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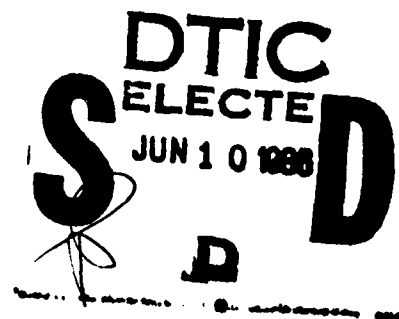
THESIS

PROPOSED MODEL FOR FORECASTING

DEMAND FOR TELECOMMUNICATIONS SERVICES

FOR THE UNITED STATES NAVY

by

Rosalind T. Bailey

March 1986

Thesis Advisor: Jack W. LaPatra

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by

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Lieutenant Commander, United States Navy
B.S., Indiana University, 1974

Submitted in partial fulfillment of the
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I. INTRODUCTION

A. BACKGROUND

A growing concern in the United States Navy regards the congestion of its communications links by message traffic. Currently, the decision to put a message into the system is made by the commanding officer of a unit or his legal designee. Although many messages genuinely need to be passed electronically through the system, many could be sent in the mail. There are several ideas being considered for alleviating the problem of congestion.

One method presently being employed at the management level is MINIMIZE. The success of this control mechanism is debatable. While many see it as effective way to temporarily head off congestion, others view it as a dam that temporarily holds up the flow of message traffic that finally results in a significantly greater flow at the point that MINIMIZE is lifted. Other controls are being studied.

One idea that has been given a great deal of high level consideration is a message screening board that would be responsible for reviewing messages to determine which of those must of necessity be passed over the system and which may be transmitted via alternative means such as the U. S. Postal system.

Regardless of the vantage point, the congestion problem could grow into a serious one, particularly if a crisis situation arises. A matter that concerns telecommunications managers is being able to ensure that the system will not be seriously degraded by the simultaneous release of a myriad of messages. Being able to forecast the demand for telecommunications services by the United States Navy is one way to evaluate risks and perhaps avert catastrophe.

This thesis looks at forecasting the demand for telecommunications from the standpoint of the private sector of the communications industry and attempts to adapt the existing forecasting models to use by the Navy. Just as private industry in interested in efficient use of its resources to increase its profits, the Navy is interested in minimizing the cost of transmitting message traffic without seriously degrading its ability to carry out its mission. This requires that a system be devised that will optimize capacity without tremendous overhead. That is, a system which will be functional in a crisis without carrying excessive overhead during lulls in the flow of traffic. Such a system requires a clear understanding of mission requirements and how they are translated into determinants of demand for telecommunications services. A clear view of future mission requirements must also be transformed into determinants of demand.

The telecommunications industry has been, and still is, dominated by the American Telephone and Telegraph system (formerly Bell Telephone). Many of the models for forecasting demand for telecommunications services have, quite naturally, been developed by the telephone industry, primarily to ensure that there is no loss of revenue as a result of underpredicting demand or that there is little profit drained as a result of higher operating costs associated with inefficient use of equipment and other resources.

B. OBJECTIVES

The purpose of this thesis is to thoroughly examine a number of forecasting models that have been employed and are currently being used by private sector forecasters in predicting demand for telecommunications services by the general public. The analysis is intended to be a comprehensive look at what the communications industry is doing to ensure that the supply of telecommunications services is as

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nearly equivalent to the demand for those services as is possible, using state-of-the-art technology as well as tried and tested expert opinion. Once the forecasting models are evaluated, the next step is to look at the requirements imposed upon the Navy's communications system in order to determine whether or not it is capable of supporting the demand for service levied by the system's users.

While this research covers some basic approaches to understanding general demand forecasting techniques, this information is not covered in great detail and is not intended to provide the reader with a review of basic economics. It is merely intended to serve as a launching pad for outlining demand theory as it relates to telecommunications service. While this thesis introduces a variety of approaches to forecasting demand for communications services, it does not cover all of the specifics for constructing each type of model.

C. ORGANIZATION

This thesis is organized into chapters, each of which states a purpose and answers relevant questions. Chapter II lays the groundwork for the rest of the study by providing a general overview of forecasting models and potential uses by managers and planners in predicting demand. Additionally, there is a general explanation of the demand function and its relationship to forecasting systems, with a segment that covers, in a general fashion, the concept of externalities and its place in demand forecasting.

Chapter III provides a detailed and comprehensive discussion of forecasting models employed specifically for the purpose of predicting demand for telecommunications or related services. Each system is analyzed in terms of its specific uses, its accuracy, ease or difficulty of application and its particular strengths and weaknesses with respect to the forecasting problem.

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Chapter IV examines the Navy's telecommunications requirements and looks at the determinants of Navy demand for telecommunications services. Using those determinants as a basis for selecting a model, the chapter discusses a variety of scenarios for the reader's consideration and offers criteria to be considered in selecting an appropriate model for meeting the needs of the Navy.

Chapter V provides a summary of the forecasting problem, the demand question and forecasting models available. Finally, the thesis is concluded with recommendations for consideration by Navy telecommunications managers and users.

II. <u>FORECASTING SYSTEMS AND THE FORECASTING PROBLEM</u>

When considering a forecasting model for predicting the demand for a good or service, there are several key issues that are vital in the selection process. It is essential that the forecasting problem be clearly understood. Answering the following questions may bring the forecasting closer to selecting the right model:

    (1)   What i. being predicted?

    (2)   How far into the future is the predicted to be?

    (3)   How much relevant historical data is available?

    (4)   What is the level of accuracy required?

    (5)   What is the method used for determining accuracy?

Although answering the above list of questions may help clarify the type of model needed, it is important to note that the one characteristic that should be uppermost in the mind of the forecast user is that FORECASTS ARE USUALLY WRONG. It is up to the user to determine the degree of accuracy that is acceptable and to know that starting with good information will only reduce the risk involved in making a forecast-based decision.

A.   BACKGROUND

This study was designed to examine forecasting models used in predicting future demand for telecommunications services. In order to embark on such a venture, it is crucial to consider the demand question. This segment provides an abridged view of the theory of demand.

1.   <u>Demand Theory and Telecommunications Services</u>

Economists generally agree that the law of demand, the quantity (Q_x) of a good or service that consumers are willing to buy during a given period, hinges upon the following factors:

    (1)   The price of the good or service (P_x)

(2) The price of substitutes/related goods or services (P_y)

(3) The consumer's income (M)

(4) The expected price of the good or service in the future (P_{t+T})

(5) The consumer's taste/preference (T)

[Ref. 1: p. 16]. These factors are called the determinants of demand. [Ref. 1: p.22]. What this means in terms of telecommunications service is that consumer's demand will be affected by the cost of gaining access to a communications network, the rental fee required for continuing service, the cost of alternative forms of communicating (such as mail, telegrams and now other long distance companies), the amount of a consumer's personal (or corporate) income and other items that must be purchased. The consumer's taste, that is, the preference for special service beyond a basic package, may in some cases be related to income.

The providers of telecommunications service must consider the consumers' utility functions when setting the prices of gaining access and the rental fee. According to the law of demand, the quantity of a good consumed will be affected by the price. In general, if the price increases for a normal good or service, the consumption will go down. It is important to note that the access fee is a one-time fee and is only considered in the demand function if the consumer opts to pay the fee. This may be denoted in a mathmatical equation as a zero or a one, 0 if access is not desired and a 1 if it is. Another important note, even if the access fee is reasonable, or even minimal, the consumer will be less inclined to want to be a part of the network if the rental fee is too high.

Another determinant of demand for telecommunications service by the consumer is the cost of substitutes or related goods or services. Prior to the divestiture of AT&T, when telecommunications was synonymous with Bell

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Telephone, competition was not an issue. The main alternative service then, was the U. S. Postal Service and still is today. However, since that landmark U.S. Supreme Court decision in 1982, the competition among new companies entering the market has given consumers additional choices, at least for long distance telephone services. With these new companies, as with the postal offices and telegraph companies, the individual consumer must evaluate the substitutes in order to rank the choices and determine whether a good or service is either inferior, superior, or indifferent. Some consumers feel that added personal services available through the larger carriers are worth the additional costs. An individual's income level may affect his or her choice of long distance carriers.

As far as the expected future price of a good or service goes, it is not likely that waiting for a reduction in the cost of renting a service would be a significant factor, however, it is conceivable that the access fee would periodically be lowered during a promotional campaign. Therefore, it is likely that some consumers may postpone joining a communications network if they had reason to believe, factual or rumored, that the cost of access would be decreasing at some future point. Conversely, information suggesting a price increase in the future may cause an increase in current demand for a communications service.

2. Elasticity and Demand

Price elasticity represents a measure of the responsiveness of demand to changes in the quantity of a good or service consumed as a result of changes in the price of the commodity. It total revenue decreases (increases) as a result of an increase (decrease) in price, then demand is said to be elastic. If, on the other hand, price rises (falls) and total revenue rises (falls), then, the demand is inelastic. A state of unitary elasticity exists if changes

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in price has no impact on total revenue. Using E to repre-
sent elasticity, the following equations may be introduced:

$$-(\delta Q/Q)/(\delta P/P) = (\delta Q/\delta P) \times (P/Q) \qquad \text{(eqn 2.1)}$$

The following results are obtained:

If $E > 1$, then, demand is elastic

If $E < 1$, then demand is inelastic

If $E = 1$, then unitary elasticity exists

The above represents the concept of own-price elasticity.
Other elasticity measures of interest to economists are
cross price and income elasticity. These measures will be
frequently referred to in this study. Understanding the
impact of these factors may reduce the risk in decision
making if the manager is observant of these and other indi-
cator and their interdependent relationships to demand for
the product of interest.

3. Cross Price Elasticity of Demand

Cross Price elasticity of a product X with respect
to product Y (E_{xy}) gives gives a measure of the percentage
change in the quantity of X consumed over a period of time
as a result of a percentage change in the price of product Y
($\delta P_y/P_y$). Equation 2.2 mathematically explains the
concept. [Ref. 2: p. 40]

$$E_{xy} = (\delta Q_x/Q_x/\delta P_y) = (\delta Q_x/\delta P_y) \times (P_y/Q_x) \qquad \text{(eqn 2.2)}$$

From equation 2.2, it can be shown that
If $E_{xy} > 0$, then X and Y are substitutes

If $E_{xy} < 0$, then X and Y are complementary   and

If $E_{xy} = 0$, then X and Y are independent

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4. Income Elasticity of Demand

The coefficient of income elasticity (E_m) measures the percentage change in the quantity of a good that would be purchased over a given period of time which would result from a given percentage change in a consumer's level of income. Equation 2.3 illustrates that mathmatical relationship:

$$E_m \ (\delta \ Q/Q)/ \ (\delta \ M/M) = (\delta \ Q/M) \ x \ (M/Q) \qquad \text{(eqn 2.3)}$$

$E_m > 0$ implies that the good is a normal good, while

$E_m < 0$ implies that the good is an inferior good.

5. Empirical Demand Functions

Empirical demand functions are the concern of managers interested in estimating the demand for a good or a service. Another concern is that of interpreting the results of the estimation. There are two primary methods for estimating demand; they are direct and regression analysis. The direct method involves the use of surveys, interviews, experiments or market studies. [Ref. 3: p. 243] Regression analysis involves the historical inspection of data points accumulated over a period of time.

a. Direct Method for Estimating the Demand Function

One way for a business entity to determine its potential for capturing a share of the market for a particular good or service is to allow every potential consumer to test its wares and have those individuals provide a list of the prices each would be willing to pay for a specific quantity of the product. A summumation of the results would provide the business managers with the exact demand for the good. Of course, the idea that every individual on earth could be contacted to provide his or her personal utility for a particular product is an absurdity. First of all, the

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cost of the study alone would be prohibitive. Second, the time it would take for the data to be compiled would probably render the results obsolete. Generally, a sample population, preferably representative of the whole population, is a survey for its demand for the product. However, there are still problems using this approach.

One problem is finding a truely representative sample. If a business manager is interested in increasing his share of a particular market, many times the response will not be reliable. For example, an automobile manufacturer may find that the demand for automobiles may be disproportionately low if he conducts his survey in one area where the economy may be depressed relative to the rest of the country.

Another problem is that there is a tendency for bias in the response. When questioned, many people will respond in terms of their intentions or desires rather than what they would actually do. [Ref. 3: p. 243] Finally, people are often unable to answer the questions accurately. Often they may not know how to interpret the question or to articulate their preferences or feelings.

b. Research Marketing

One of the most widely used techniques for estimating consumer demand for a good is through price-only adjusting. A marketing research group will place its product in the market and adjust the prices in small increments and record the changes in the quantity sold as a result raising and lowering the price. This technique allows market analysts to determine own-price elasticity of demand for its product and to make informed decisions regarding how much will be produced, at what costs and the ultimate price that consumers are most likely to pay, all other things being equal.

6. Forecasting Demand

Forecasting methods can be divided into two major categories--qualitative and quantitative. Qualitative models are generally more difficult to depict because they are subjective. Conversely, quantitative models, while easier to define mathematically, are not necessarily easier to understand.

B. QUALITATIVE FORECASTING MODELS

The subjectivity of this category of models makes it more difficult to provide a clear unambiguous description of the concept. Much of qualitative forecasting is based upon intuitive evaluation of information available as well as by surveying the opinions of other "experts". While a great many of the qualitative judgments may be based upon the best information, the decisions that will be derived will ultimately be considered subjective too. Within this group of models are expert opinions, the delphi technique, and opinion polling.

1. The Delphi Method

Although this method dates back to 1948 with the Rand Corporation, it became a very popular decision making tool in the early 1960's. Still quite popular in the 1980's, it involves the use of expert opinion that is systematically formulated and modified in order to arrive at an optimal decision. The expert opinions are anonymously submitted, usually on an elaborately drawn questionnaire until a convergence of opinion is arrived at through an iterative process. [Ref. 4: p. xi] The Delphi method is a useful tool when the information needed has little lead time and forecast preparation cost is a major concern. It is relatively fast and inexpensive and is particularly useful when a new organization is forming with a small data base. Experts with experience in similar fields are often able to provide useful information that can not be summoned from a computer data base.

A major criticism of the technique is its defiance of scientific principles; in particular, the same process, when repeated, does not always yield the same results. [Ref. 4: p. 3]

2. Marketing Research

This technique involves a formal, systematic process for developing and evaluating hypotheses about actual markets. Particularly useful for short-ranged forecasting, this method is frequently employed for predicting future sales for new products. A great deal of data needs to be accumulated in order for this method to be most successful.

3. Historical Analogy

Historical analogy is a method based on comparative analysis of similar products. This method is frequently employed when little or no data is known about the marketability of a new product to be introduced. Of all of the qualitative methods discussed here, this approach is viewed as a relatively poor barometer from a forecasting perspective.

C. QUANTITATIVE TECHNIQUES

Quantitative, or statistical approaches as they are sometimes called, are more easily defined and measured as one might expect. This group of models is subdivided into two categories--time series and causal models. [Ref. 5: p. 263] A time series is a time-ordered sequence of observed behavior of a variable. Generally, time series models require the use of historical data on a variable for the purpose of projecting future behavior. Hence a mathmatical model is needed to represent the process whereby predictions for the future may be made.

Causal models are characterized by the use of explicit structural models that attempt to define the underlying economic relationships. At the heart of such models exist the relationship between the interesting time series and one

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or more time series. The focal point of the model is a correlation between the variable of interest and some other variable. If a correlation can be determined, it is possible to construct a statistical model that will mathematically explain the relationship. One advantage to using causal models is that the models require that a clear explicit causal relationship be defined. Further, it allows sensitivity analysis to be performed on the variables. And finally, this approach can be easily adapted to simulations models.

On the other hand, the greatest limitation to using causal models is the stipulation that the independent variable must be known at the time the forecast is made. Another disadvantage in the use of econometric models is the huge amount of data that must be processed in the estimation process.

Most forecasts for demand use both qualitative and quantitative parts in order to derive the most optimal managerial decisions. Probably not enough emphasis can be placed on the importance that human behavior plays in forecasting demand. Organizations have a corporate personality that varies from one company to another. Each group has its own set of norms and mores that are unique and an explanation or quantification can probably only be attempted by the most experienced observers.

In the sections to follow, a more in depth discussion on the major categories of forecasting models will be given. That will be follow up in Chapter III by a detailed discussion of models used in forecasting demand for telecommunications services.

D. TIME SERIES MODEL

A time series, as previously mentioned, is a time-ordered sequence of observations of a variable. The observations are generally equally spaced along a continuum. The

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analysis of time series data allows the analysts to make predictions of future behavior by the variable based on the assumption that the future will be like the past. An important word of caution regarding the use of time series models may be helpful. The prediction horizon for time series forecast should not be extremely long-ranged. Studies have shown that the further away the prediction is from the historical data, the less likely the chance of achieving an acceptable degree of accuracy in the prediction.

Time series models may be represented by a number of variations. Figure 2.1 illustrates the most commonly known varieties. The symbol x_t depicts an observation for a given period t. Figure 2.1 (a) represents a constant level in the behavior pattern. In figure 2.1 (b), a pattern illustrating a linear trend is represented. Figure 2.1 (c) is representative of a linear trend that also demonstrates a cyclic pattern. while

1. Trend Projection Models

This method fits a trend line to a mathematical equation which is then used to project future behavior of the variable in question. Two most widely used are the simple linear trend and the polynomial curve. In general, this method is one of the most simple to implement and requires very little lead time, provided that an adequate data base is in existence.

a. Linear Trend

This model is a straight line forecast which represents the behavior of a series of data points observed over a period of time. The model is fitted to the data points using the system of least squares. This model is most useful when it is reasonable to assume that the behavior of a variable will be linearly related to the passage of time. [Ref. 6: p.12]

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(a) Time Series with A Constant Pattern

(b) Time Series with an Upward Trend

(c) Time Series with a Cyclic Pattern
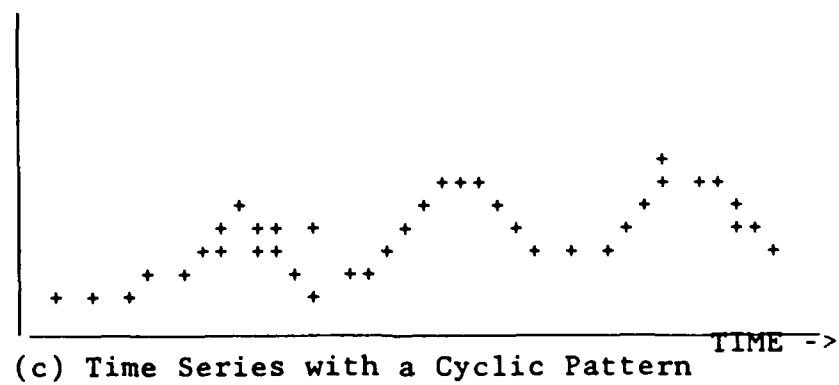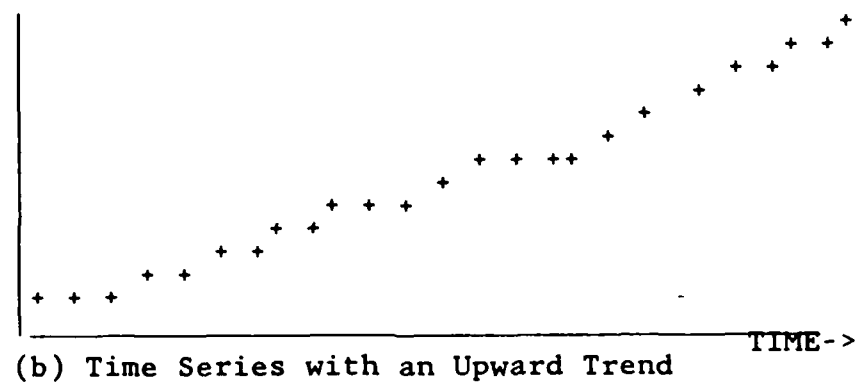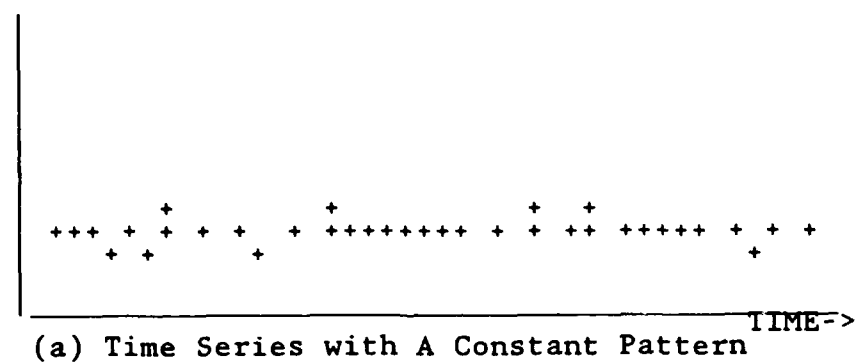
Figure 2.1   Time Series Models.

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b. Polynomial Curve

The polynomial curve can be used when it appears that the data points do not follow a straight line. Using a second order polynomial will render a type of saturation curve. This variation is appropriate when the forecaster has reason to believe that the forecast will ultimately reach a plateau. In a second order polynomial, time is squared, while in a third order polynomial, time is cubed. [Ref. 6: p. 12]

2. Moving Average

More flexible than either the linear or polynomial models, the moving average is derived by taking the mean over a given number of time periods. For example, if it is deemed by the forecaster that only the last five periods are significant, those five periods are averaged together and used to project the following period. This model is most beneficial when either a downward or an upward trend is observed. The moving average is not considered to be a very reliable or accurate predictor.

3. Exponential Smoothing

Exponential smoothing models use past observations to develop forecasts. And while similar to moving average models, this form requires that different weights be assigned to each observation. Generally, more weight is given to recent data points and less to older data. With the use of a smoothing constant, weights between 0 and 1 are selected by the forecaster. There are several variations of this technique ranging from simple to very complex. Many computer programs are available that employ this type of model. Results are quickly generated.

4. Holt-Winters

The Holt-Winters method is a more sophisticated version of exponential smoothing. This method allows the analyst to examine seasonal trend patterns in the data.

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[Ref. 7: p. 4] Preparation time for this model is relatively short and this approach is useful if lead time is minimal. Advantages include its relatively small data requirement, its low cost and its ease of understanding. In terms of accuracy, it is more reliable than conventional exponential smoothing. [Ref. 7: p. 10]

5. Box-Jenkins

Another model closely related to the exponential smoothing technique, Box-Jenkins takes time series data mathematically fitted in such a manner that it assigns smaller errors to history than other models. For short term forecasting, these models are currently the most accurate and reliable. One major disadvantage with the model is that it requires tremendous skill of the forecaster in selecting the best model from the several models available. Another drawback is the expense associated with computer time. Additionally, Box-Jenkins are considered to be among the most difficult to understand conceptually. [Ref. 7: p. 9] This class of models are also known as Autoregressive Moving Average (ARMA) models.

6. Decomposition

This technique is most useful in dealing with trend seasonality and cyclical data. It allows the analyst to "deseasonalize" the data. It is considered to be simple, easy to use and the results are easy to interpret. For short term forecasting, it is very accurate. A disadvantage of the decomposition technique is that the required intervention by the analyst renders much of the forecast arbitrary. [Ref. 7: p. 5]. The Census X.11 is a widely used decomposition technique.

7. Bayesian Forecasting

This forecasting technique is based on the premise that subjective forecasts can be translated into Bayesian estimates of the parameters of the forecasting model.

[Ref. 8: p. 241]. Using a technique called Kalman filtering, the estimates are updated as additional data becomes available. Bayesian forecasting makes it possible for the analyst to specify a range of models for the data, vice a single model, along with probabilities that are also updated as the new information is introduced.

E. CAUSAL MODELS

As previously mentioned, causal models require that the analyst identify other variables that may be related to the variable to be predicted. A model is then developed to mathematically depict the relationship between the variables. This model is then used to predict the behavior of the interesting variable. Several of the most well-known causal models are described in this section.

1. Multiple Regression

This technique is used to formulate estimates for the coefficients of the independent variable in a regression equation. A regression equation describes the relationship between the dependent and independent variables and is then used to make predictions on the value of the dependent variable.

2. Multivariate Box-Jenkins

A more sophisticated version of the Box-Jenkins, this method attempts to relate independent variables to dependent variables by the use of transfer functions. [Ref. 9: p. 5] The data requirements in this model are great and a long lead time is needed. It is extremely complicated and one of the most difficult for managers to comprehend. Another disadvantage with this model is the excessively high cost. There is not enough evidence available to say that the multivariate versions of Box-Jenkins models are any more accurate than the single variable varieties.

F.   ECONOMETRIC MODELS

This category of models are also frequently referred to as causal models because this approach to forecasting requires that explicit underlying relationships be explained. An advantage to having such a correlation specified is that it allows the analyst to discount spurious data points when evaluating results. Another advantage with this group of models is the ability to perform sensitivity analysis of the variables of interest. The measures of these elasticities have proven to be most vital in most modern approaches to understanding and forecasting demand. [Ref. 10: p. 277]

G.   FORECASTING SYSTEMS: THE WHOLE STORY

The beginning of this chaptered offered some questions that should be considered when selecting a model for forecasting demand. Answering those questions is only the beginning of the decision process. Once a forecast is made, other factors must be considered in order to complete the process. The forecasting model must be part of a total system. Figure 2.2 illustrates the concept of a total forecasting system. The system must be one that surveys the forecasting problem prior to selecting an appropriate model. The forecast is made by taking into consideration the expected accuracy. The behavior of the forecasted variables are monitored on a tracking system. The forecast is then adjusted to reflect the latest information available.

An integral part of the forecasting system is the forecast monitoring system. This segment of the model is needed to attempt making an overall forecast as accurate and as reliable as possible. A key component in the tracking system is setting up a range of acceptable limits, a confidence interval which will give the manager an idea regarding the probability that the forecasting model will actually predict what it is supposed to predict.

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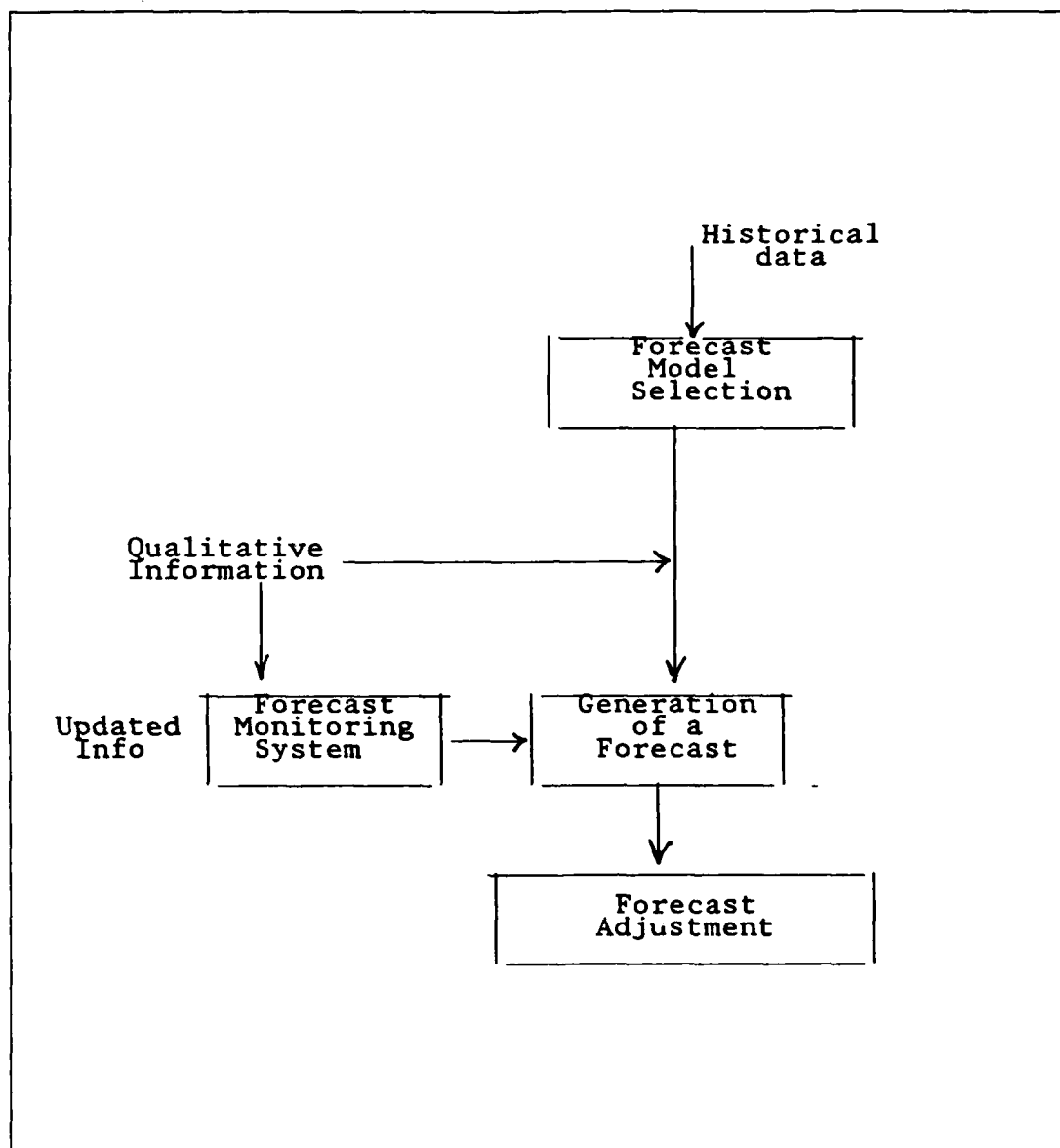
Figure 2.2   Total Forecasting System.

In general, the monitoring system tests the accuracy of the model by comparing actual data points with predicted data points. This can be done in one of two ways. One way is to actually follow the progress of the variable behavior and compare the variation. Another way is to use historical data to extrapolate "future" data points for a period of

time that has already past. The advantage to using the
second approach is that the accuracy can be testing immedi-
ately and before the technique is actually needed.

Like all forecasting systems, the forecast monitoring
system is merely a mechanism for assisting the decision
maker in selecting the most optimal choices available. One
should guard against false security that might accompany a
high confidence interval which has "predicted" data points
with a high level of accuracy up to the present time. A
confidence interval of 99% only indicates that the prob-
ability that a forecast will be correct is extremely high.
There still exists a small probability that the forecast
will be wrong. Additionally, there may be exogenous vari-
ables that could change drastically over the period of
interest which may render the results totally useless.

III. MODELS FOR PREDICTING DEMAND FOR TELECOMMUNICATIONS SERVICES

A. PUTTING THINGS INTO PERSPECTIVE

The main purpose of this chapter is to analyze and evaluate models for forecasting demand for telecommunications services that are currently being used by the telecommunications industry. This chapter will closely examine several models for predicting demand by first looking at determinants for the demand for communications services. Since most of the current literature makes a distinction between the demand to gain access to a telecommunications system and the demand to utilize the service once access has been attained, it would be convenient to focus on the differences and to categorize the models based on that distinction. However, such an undertaking would be beyond the scope of this thesis. Instead, this study will concentrate primarily on models that attempt to predict use.

The chapter will begin by first examining the difference between the two types of models. That will be followed by a discussion of access forecasting models, then by statistical models for forecasting the demand for use. The presentation of each model will include a discussion of the model, its applications, its potential for long-ranged versus short-ranged forecasting and an analysis that focuses on the model's strengths and weaknesses.

B. ACCESS MODELS VERSUS USAGE FORECASTING

There has long been a movement in our society to quantify everything quantifiable and to translate unquantifiable needs and desires into numbers that can be interpreted into expected human behavior. Marketing researchers and economic forecasters have probed, experimented, collected, dissected,

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analyzed, synthesized, quantified and computerized nearly every aspect of human behavior in an effort to understand why we do the things that we do. By examining all of the known factors and correlating observed behavior with events that occur in our environnment, it is hoped someone will design a model that will be able to accurately forecast how we will behave given a certain set of circumstances. The ultimate goal for a profit making organizaton is to find out what makes us tick and to try to push the right buttons-- those that will cause us to want their product more than another's and then cause us to buy their products.

Generally, forecasting models are classified by the way that data and information are used to ultimately predict the future demand for a good or service. Those models for fore- casting are considered to be either qualitative, relying heavily on expertise and judgment, or quantitative, calling for great volumes of numbers to be crunched into a computer that will spit out a nice clean readout. In the actual forecasting that goes on, there is often blending of quali- tative and quantitative techniques in predicting demand.

Because of the blending that goes on, it would be most convenient to divide the models into two major categories that will take this fact into account. The first type, access models, focus primarily on translating the determi- nants of demand into a model for forecasting the demand. This category of models require the authors to make certain limiting assumptions. However, such assumptions are very necessary to ensure that those who will ultimately be using the information are aware of the models' limitations as well as its capabilities.

The second class of models, usage models, are generally time-series models that rely heavily on computer data bases filled with electronically collected and stored information on how many trunk lines are in use during the busy hour and the origin and destination of those calls.

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C. ACCESS MODELS FOR FORECASTING DEMAND

Models in this category tend to require a great deal of judgement and expertise. Many of the estimates are empirically determined since it is very often impossible to account for all of the factors that impact on demand. As pointed out in Chapter II, many of those wishing to have a particular good or service may not really know why he/she wants to have it. The models in this section attempt to quantify variables that are very often only quantifiable in theory. Forecasting the demand for a good or service must start with a firm foundation. The characteristics of that foundation include information/data, clearly defined determinants of demand, clear unambiguous and realistic goals and a forecast accuracy monitoring system. Chapter II provided a brief description of many of the determinants and how they figure into the demand function. Table I provides an expanded general summary of the determinants generally associated with telecommunications services that ought to at least be considered when structuring a model for estimating demand. The list is by no means exhaustive and must be tailored to conform with the requirements of the organization and the reason for assessing demand.

The next step is to formulate an expression that will allow the analyst to estimate the demand. Since so many functions for estimating demand for telecommunications services are empirically determined, the task is not a simple one. This section focuses on several models currently used by the telecommunications industry for estimating the demand for a service.

D. MODEL FOR INTERDEPENDENT DEMAND

1. Description

This model is one of a number of models based on a theory of interdependent demand for a telecommunications service. The basic assumption is that an individual's

```
TABLE I

DETERMINANTS OF DEMAND FOR
TELECOMMUNICATIONS SERVICES


            Dependent Variables
.number of telephone calls/messages/telegrams
.number of packets


            Independent Variables
.average price of a phone call
.average price of a message
.average price of a packet
.average price of hook-up costs
.average prive of first class letter
.average price of a round trip airline ticket
.average price of teleconference call
.total budget allocated to telecommunications
.total income (individual vs aggregate)
.population and growth rate
.total number of users connected to network
.local level of urbanization
.time zone
.common business hours
.similar interests
.business connections
.economic activity
.quality of service
.accessibility of system
.familiarity of system
.profitability of service
```

utility derived from a communications service increases as the number of subcribers to the service increases. [Ref. 11] The model begins by defining the equilibrium user set as a set of users which consists of the total number of individuals (users and nonusers) maximizing their utilities. In Rohlf's own words:

> For example, a very small equilibrium user set may be consistent with utility maximization, since the smallness of the user set itself makes the service relatively unattractive to potential users. However, a much larger user set may also be possible for the same population at the same price. In this case, the largeness of the user set would make the services attractive and allow a high level of demand to be sustained. [Ref. 11: p. 18]

In essence, a large user set would have a correspondingly higher level of demand for a communications service.

Rohlf proposes that either an individual is a subscriber or not. He further assumes that there are other goods in the economy that may be of interest of the individual consumer. Next, he assumes that each individual possesses a pair of utility functions. The above assumptions are expressed in the following manner: Using a set of binary variables [Ref. 11: p. 19].

$q_1 = 0$ if individual i does not join   (eqn 3.1)
the communications network

$= 1$ if individual does join the
communications network

The other goods that might be purchased by individual i are represented by m, while interdependence in the model is expressed by a pair of utility functions for each individual:

$$U_i^0 = U_i^0 \ (r_{i1} \ldots r_{im}) \qquad\qquad \text{(eqn 3.2)}$$

$$U_i^1 = U_i^1 \ (q_1, \ldots q_{i-1}, \ q_{i+1}, \ldots q_n, \ r_{i1} \ldots, r_m \quad \text{(eqn 3.3)}$$

Where

U_i^0 = Utility of individual i if he/she does
not join the communications network

U_i^1 = Utility of individual i if he/she does
join the communications network

r_{ij} = Consumption of other good j by individual i

Several assumptions that are made regarding communications services are as follows:

(1) subscriber's utility never decreases as other members join

(2) no subscribers drop out

(3) prices of all other goods other than communications services are fixed

(4) each subscriber's budget is fixed

(5) utility is maximized with respect to an individual's budget constraint

Taking the above assumptions into account, it is possible to define an individual demand variable as:

$$q^d = \begin{array}{l} 0 \text{ if } U_i{}^0 > U_i{}^1 \\ \\ 1 \text{ if } U_i{}^0 < U_i{}^1 \end{array} \qquad \text{(eqn 3.4)}$$

Where $U_i{}^0$ and $U_i{}^1$ represent maxima of $U_i{}^0$ and $U_i{}^1$ with respect to $r_{i1}...r_{im}$. In plain English, the demand variable for individual i is 0 if he/she does not subscribe to the telephone system and 1 if he/she does subscribe to the system. In essence, all users demand a telecommunications service and that all nonusers do not.

2. Applications

The contribution made by Rohlfs in structuring this model focuses on his two-step maximization function that begins by first evaluating an individual's utility for telephone service with or without access and then determining the individual's demand by comparing the utility levels. This aspect of the model appears to be representative of actual human behavior. [Ref. 12: p. 241]

If this theory is correct, it may be more beneficial for the industry to lower the price of the service if it means a larger network, which by definition would increase the aggregate utility, which in turn may increase the aggregate demand for the service. In his discussion of the theory, Rohlfs suggests that this increased utility may offset any loss that may be incurred as a result of lowering

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the user's price of joining the telecommunications network. [Ref. 13: p. 17]

3. Model Strengths and Weaknesses

    a. Strengths

One of the model's strengths is that it is easy to understand. While as a model for forecasting, it falls short, it serves as a good place to start by allowing the user to define what the curve that depicts demand might look like. As mentioned previously, it evaluates an individual's utility and demand in terms of a two-step function.

    b. Weaknesses

One of the problems one might encounter with this as well as with most empirical demand functions is that some of the assumptions are unrealistic: For example, it assumes that an individual's utility never decreases and that a user will never drop out of the system. Another problem has to do with its usefulness for assessing aggregate demand. The theory does not provide a way to explain how an individual's demand will impact on the entire system. Perhaps the most obvious failing is that the author really makes no distinction between access and use. It assumes that there is just one price of being a part of the network when in real life there is the price of joining and the price of placing calls. Furthermore, there are different prices based on the time of day and the place called.

E. UNIFORM CALLING PATTERN MODEL

1. Description

A forerunner of Rohlf's theory of interdependent demand, the Uniform Calling Pattern Model by Artle and Averous starts with a population consisting of N individuals. A set of binary variables is once again presented such that

$q_i = 0$ if individual i does not

    subscribe to the telephone service

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= 1 if individual i does

subscribe to the telephone service

The model developers made several assumptions regarding the N members in the population which lead to the existence of two mutually exclusive subsets of individuals who either have access (G_1) or not (G_0): [Ref. 14: p. 17]

(1) all the members are a group who enjoy talking to each other

(2) each individual converses with every other individual either face-to-face or over the telephone

(3) if a member of the group does not subscribe to the phone service, he/she has no access to the system at all

Artle and Averous define the utility function for individual i (U_i) as consisting of his membership among a set of individuals who either have access to the telephone system or not and all other goods and services. The expression for the utility function is

$$U_i = U_i(x_i, q_i) \qquad \text{(eqn 3.5)}$$

Where x_i represents all other goods and services and q_i equates to membership status. In 3.6, q_i is defined as follows:

$$q_i = q \text{ for all } i \text{ in } G_1 \qquad \text{(eqn 3.6)}$$

$$0 \text{ for all } i \text{ in } G_0$$

A binary set exists since an individual either has access to the system or not. Therefore, a dummy variable, δ_1, is introduced, where $\delta_1 = 1$ if the ith individual has access and 0 if the ith individual does not have access to the system. The resulting utility function is of the form: [Ref. 14: p. 18].

$$U^i(x^i, \delta^i, q^i) \qquad \text{(eqn 3.7)}$$

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From there two utility functions may be postulated to exist
for individuals with or without telephone service. They are

$$U^1 = U^1 (x^1, \delta q), \delta = 1 \qquad\qquad \text{(eqn 3.8)}$$

$$U^0 = U^0 (x^0, 0), \delta = 0 \qquad\qquad \text{(eqn 3.9)}$$

Where q is measured by the number of telephones. Therefore,
q of the total population N individuals are connected to
each other by telephone and N-q represents the number of
individuals outside of the telephone system. [Ref. 14: p.
19] Figure 3.1 illustrates the demand curve for the Uniform
Calling Pattern. The demand curve depicts equilibrium user
sets for all individuals. A user set is represented by a
point on the curve. For any q, there is one and only one
equilibrium user set with q members all having the same
maximized utility. *The Uniform Calling Pattern Model* allows
the following equations to be written for a large popula-
tion: [Ref. 15: p. 27]

$$q_i^P = 0 \text{ if } f_{wi} < p \qquad\qquad \text{(eqn 3.10)}$$

$$1 \text{ if } f_{wi} > p$$

Where f = the user fraction (q/n), and

$$w_i = \Sigma w_{ij}$$

Where w represents an individual's utility for the service.
        The solution allows individuals to be ordered in
terms of their demand for the service. $w_i > w_j$, means that
individual i's demand for the service is greater than indi-
vidual j's demand. In order for the equilibrium user set to
exist, all members in a set must have the same maximized
utility.
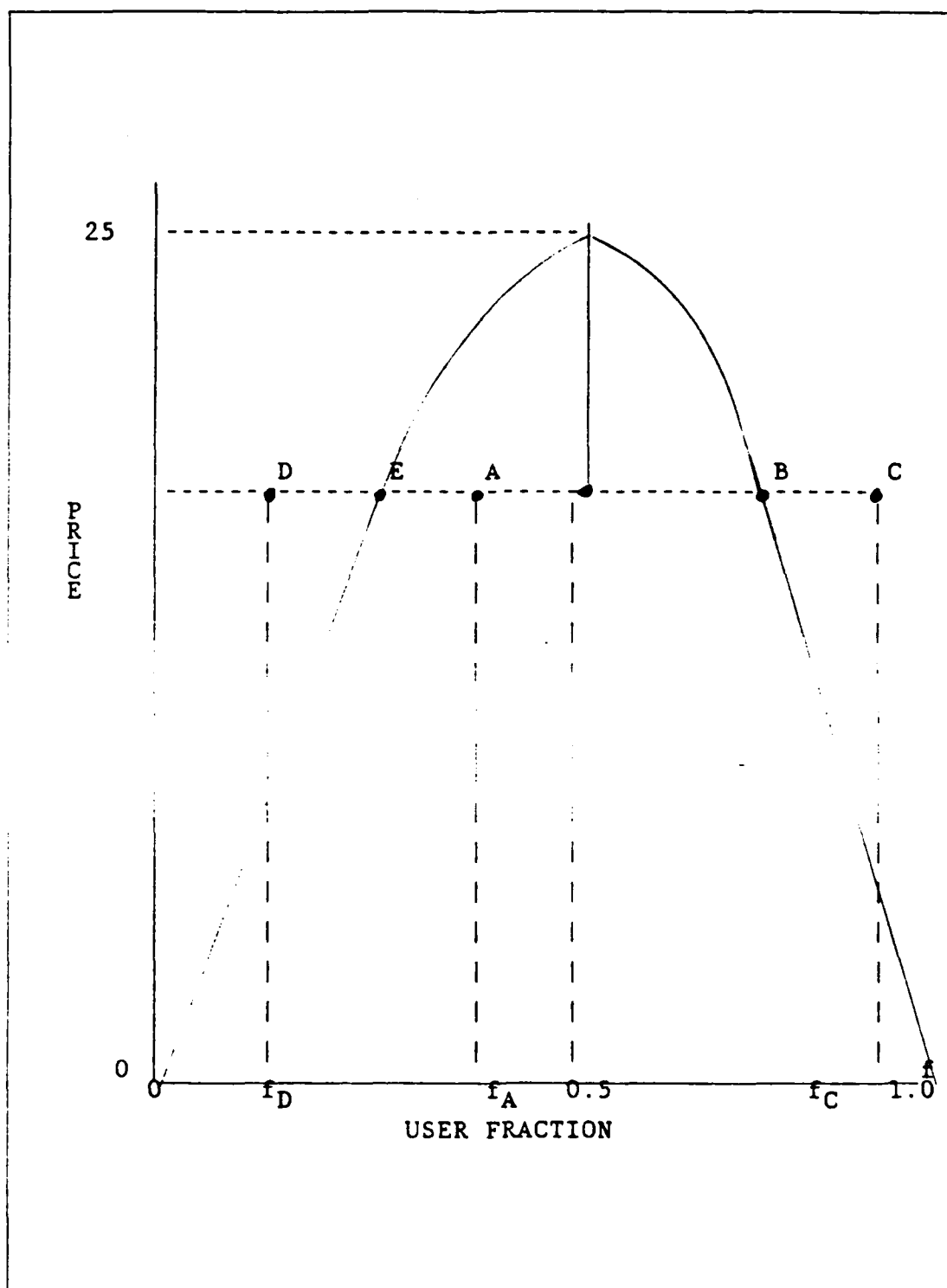
Figure 3.1   Demand Curve for Uniform Calling Pattern Model.

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2. Model Strengths and Weaknesses

Artle's and Averous' Uniform Calling Pattern Model defines the access/no access decision and provides a possible explanation for the growth of the network even though the population itself remains constant. However, as a theory for the demand for telecommunications, it does not adequately describe how to determine the demand for a tele-communications service in a manner that might be employable for an actual assessment project. The biggest problem lies with the assumptions that are made in designing the model. First of all it assumes away the demand to use the service by stating that everyone in the system communicates face-to-face. If that is the case, there is no need to have a telephone. Second, it is unrealistic to assume that if a person does not have a phone that he will not use a pay phone or a neighbors phone. Third, the model ignores the possibility that there are people who wish to communicate with people that they do not already know.

F. DEMAND FOR INTERNATIONAL TELECOMMUNICATIONS

A limited number of record carrier companies in the United States and around the world are concerned with providing telecommunication services to users interested in making world-wide connections. Those services generally fall under the classification of telephone, telegraph and telex. Carriers in this business need to have accurate forecasts in order to meet both grade-of-service require-ments for the users and to ensure an equitable return on its investmentsa for its shareholders.

Rea and Lage constructed a model of the demand for international telecommunications service using combined telephone, telegraph and telex data for the period 1964-73. From that data, they formulated demand equations to estimate the demand elasticities for communications via 37 major routes and to extrapolate the demand elasticities for 1974.

The significance of the concept of elasticities, covered in the previous chapter, is well-worth reiterating here. Own-price elasticity represents a measure of the responsiveness of demand to changes in the quantity of a good or service consumed to changes in the price of the good or service, ceteris parabis. Additionally, the reader is invited to recall the importance of cross-price elasticity, the effect of price changes in complementary or substitute goods on the quantity consumed; and of income elasticity, the impact of a change in the consumers income level.

Another important fundamental concept that ought to be mentioned before looking at the specific models, is that of multiple regression and nonlinear equations. Multiple regression (of two or more independent variables) makes it possible to estimate an equation for a line that will give the best fit. The best fit may be a linear equation, but often it is not. One kind of nonlinear equation refers to the nonlinearity in its parameters. The form that is easily interpreted is

$$Y = \alpha \, X^\beta \, Z^\gamma$$

This form is especially useful because the parameters β and γ measure elasticities. Recall that

β = percentage change in Y/percentage change in X
  = $(\Delta Y / \Delta X) \times (X/Y)$ and

γ = percentage change in Y/percentage change in Z
  = $(\Delta Y / \Delta Z) \times (Z/Y)$

The functional form allows direct estimation of elasticities. However, in order to estimate the function, it is necessary to take the logarithm of $Y = \alpha \, X^\beta \, Z^\gamma$, to get

$$\log Y = (\log \alpha) + \beta \, (\log X) + \gamma \, (\log Z)$$

[Ref. 16: p. 75] Rea and Lage determined that the demand for telecommunications services were best described in that particular study by the nonlinear equation discussed in this section. They postulated that the respective demand functions for telephone, telegraph and telex could be estimated by the following equations: [Ref. 17]

(1) $\log TP = \alpha_0 + \alpha_1 \log (PTP/P) + \alpha_2$
$\log (PTG/P) + \alpha_3 \log (PTX/P) + \alpha_4 (TRADE/P) +$
$\alpha_5 \log (DISINC/P) + \varepsilon_1,$

(2) $\log TG = \beta_0 + \beta_1 \log (PTP/P) + \beta_2$
$\log (PTG/P) + \beta_3 \log (PTX/P) + \beta_4 (TRADE/P) +$
$\beta_5 \log (DISINC/P) + \varepsilon_2,$ and

(3) $\log TX = \gamma_0 + \alpha_1 \log (PTP/P) + \gamma_2$
$\log (PTG/P) + \gamma_3 \log (PTX/P) + \gamma_4 (TRADE/P) +$
$\gamma_5 \log (DISINC/P) + \varepsilon_3$

Where TP = quantity demanded for telephone service
        TG = quantity demanded for telegraph service
        TX = quantity demanded for telex service
        PTP = price index for telephone service
        PTG = price index for telegraph service
        PTX = price index for telex service
        TRADE = dollar value of total made between U.S.
             and foreign country to which service is
             directed
        DISINC = disposable household income
        P   = index of general prices
        $\varepsilon_1, \varepsilon_2,$ and ε_3 = random disturbances
        α, β and γ = elasticities of demand

The information is summarized in Table II which lists and defines the determinants of demand in the study of international telecommunications service for the 1964-73 time frame.

Three important limitations imposed by the data restricted subsequent analysis. [Ref. 17: p. 366] First, use of the aggregate measures of disposable income and total trade to estimate the constraints in the demand function were determined to be too broadly defined. Due to the unavailability of some necessary data, approximations were used instead. Second, the prices for telecommunications services were regulated by the Federal Communications Commission, not determined by the marketplace. Therefore, all of the independent variables are exogenous which means that the problem of solving simultaneous equations does not exist. Unfortunately, while the demand equations are easily identified, it is not possible to determine whether or not supply has been adequate to meet the demand. And finally, there exists the problem of aggregating the data. This is primarily due to the difference between residential telecommunications versus business communications requirements [Ref. 17: p. 367] The calling patterns of residential users tends to be more affected by changes in the price of placing overseas calls than the patterns of business entities.

In order to avoid the problem of imposing a uniformity of behavior on the various routes used, Rea and Lage used two different models, the covariance model and the error component model in order to allow for any individual differences between the routes. To begin, both models were evaluated using the following general demand equation for the three telecommunications services:

$$\gamma_{it} = \alpha + \Sigma \ \beta_k \ X_{itk} + w_{it} \qquad\qquad \text{(eqn 3.11)}$$

$(t = 1 \ldots j, \ T_{ji=1}, \ N)$
Where i = route

t = time period

γ = dependent variable

X = independent variable

α and β = constant unknown parameters

w_{it} = general disturbance term with the property

$$E(w_{it}) = 0 \quad \text{where}$$

$$E(w_{it}w_{js}) = \sigma_w^2 \text{ for } i=j, \; s=t$$
$$0 \quad \text{all other times}$$

G. COVARIANCE MODEL

1. Application

Referring to equation 3.11, a major difference between the covariance and error component models pertains to the treatment of u_i and v_t. In the covariance model, the terms are regarded as unknowns subject to the following:

$$\Sigma \, u_i = \Sigma \, v_t = 0 \qquad \qquad \text{(eqn 3.12)}$$

Translated, the intercept in equation 3.11 is postulated to be shifting from route-to-route and from period-to-period. One assumption that is made concerning this model is that factors such as overlapping business hours, language simi-larities, tourism, speed-of-service and quality of service affect the demand for a telecommunications service differ-ently dependent upon the route, but remains constant over time. The equation is estimated by regressing the dependent variable on the independent variables. The estimates are called dummy variable least squares (D.V.L.S) estimates. [Ref. 17: p. 368]

H. ERROR COMPONENT MODEL

1. Application

Again, with reference to equation 3.11, the difference between the covariance model and error component model focuses on the way that u_i and v_t are handled. In the error component model they are treated as independent random variables. Also, assumed to be independent of w_{it}, u_i and v_t have the property $E(u_i) = E(v_t) = 0$,

$$E(u_i u_j) = \sigma_u^2 \text{ for } i=j$$
$$0 \text{ for } i=j$$

$$E(v_t v_s) = \sigma_v^2 \text{ for } s=t$$
$$0 \text{ for } s=t$$

It can be stated that the random variables might reflect an error in measurement or an aggregation of smaller effects that are specifically related to a particular route or a given time period. [Ref. 17: p. 368]. Assuming that there is randomness in u_i and v_t, the disturbance noted in equation 3.11 is expressed by $E_{jt} = u_i + v_t + w_{it}$. Thus, the following can be postulated:

$$E(\varepsilon_{it}) = 0 \quad \text{and}$$

$$E(\varepsilon_{it}\varepsilon_{js}) = \sigma^2 \text{ for } i=j, s=t$$
$$\sigma_p^2 \text{ for } i=j, s=t$$
$$\sigma_\lambda^2 \text{ for } i=j, s=t$$
$$0 \text{ for } i=j, s=t$$

The assumptions of the Generalized Linear Regression Model are satisfied by ε_{it}. Thus, the generalized least squares (G.S.L.) estimates may be used to estimate β For convenience as well as simplicity and without going into great detail, the empirical results of both the covariance and the error component models are summarized in Table III for telephone demand.

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                          TABLE II

        DETERMINANTS FOR INTERNATIONAL TELECOMMUNICATIONS


                        Independent Variables*

     DISINC    Total United States disposable income
                  in current dollars
     TRADE     Sum of exports of merchandise and
                  imports of merchandise between
                  U.S. and each country used in sample
     PTP       Price of 10-minute telephone call
                  computed as average of all
                  such calls
     PTX       Price of 2-minute telex message
     P         Implicit price deflator for gross
                  national product

                        Dependent Variables*

     TG        Series of outbound telegram messages from
                  U.S. to each sample country
     TP        Series of outbound telephone calls from
                  U.S. to each sample country
     TX        Series of outbound telex messages from
                  U.S. to each sample country


     *Note:  All variables are measured annually.
```

The period 1964-73 is used to evaluate the equations for both models. The estimated telephone equations' results for both models are very similar. With two exceptions, the corresponding regression coefficients in each equation have the same sign with magnitudes that are nearly the same. The elasticity results indicate that telegraph service is esti- mated to be complementary to telephone service, while telex is estimated to be a substitute. [Ref. 17: p.371]. Other observations from the table reveal that the demand for tele- phone service is closely related to the prices of telephone calls, telegrams and income. The demand for telephone service is very price elastic according to the results.

TABLE III

DEMAND FOR TELEPHONE SERVICE

Time period	Estimator	Degrees of freedom	Intercept	TRADE	PIP	PTX	PTG	DISINC	t-statistic for significance of route effects	s^2	β	σ^2	R^2†
(i) 161-73	D.V.LS.	328	1.801 (0.709)	0.357 (0.635)	−0.548 (0.871)	0.281* (0.150)	−3.171 (0.391)	2.971 (0.492)	32.915	0.101			0.964
(ii) 161-73	G.L.S.	364	0.754 (0.283)	0.520 (0.654)	0.725 (0.153)	0.810 (0.156)	−2.933 (0.390)	2.624 (0.162)		0.355	0.693	0.422	0.810
(iii) 161-68	D.V.L.S.	143	5.702* (3.679)	0.477* (0.184)	−0.043* (0.045)	−0.043* (0.237)	−2.209 (0.877)	3.827 (0.624)	36.654	0.054			0.967
(iv) 166-73	D.V.L.S.	143	8.609 (0.941)	0.642* (0.113)	−1.718 (0.264)	0.353* (0.162)	−1.425 (0.417)	2.654 (0.264)	32.360	0.045			0.961
(v) 164-68	G.L.S.	179	0.709* (0.527)	0.615 (0.070)	0.712 (0.225)	0.044* (0.231)	−2.873 (0.418)	2.589 (0.263)		0.318	0.760	0.437	0.724
(vi) 169-73	G.L.S.	179	3.453 (0.460)	0.443 (0.178)	1.915 (0.283)	0.304 (0.187)	−1.016 (0.398)	1.923 (0.207)		0.297	0.835	0.326	0.743

* The estimated coefficient is not significantly different from zero at the 5% level. For the D.V.L.S. estimates, the test is based upon the t distribution. For G.L.S. estimation, the test is based upon the asymptotic distribution, which is normal.

† The adjusted multiple coefficient of determination (R^2) as computed by the formula $1 - s^2/\hat\beta$, where s^2 is the estimated variance of the disturbance $\hat\sigma^2$ and $\hat\beta$ is the estimated variance of the dependent variable.

‡ The dependent variable has been divided by P, the implicit price deflator, and is in logarithms.

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I. SCENARIO BUILDING

Scenario Building involves forecasting demand for a good or service by examining a variety of likely situations that may impact on the level of the demand. Like other techniques, it starts out with at least an empirical analysis of the determinants of demand for a telecommunications service. At best, scenario building is an art that can be most effective in a forecasting situation when little or no hard data is available. However, through the use of computer software, simulation models are being designed to marry the art with science in a move to make operating a business more predictable.

1. General Description of Scenario Models

Building scenarios is one method that could benefit most from expert opinion that might be obtained through the Delphi technique. Using the available information, enhanced by informed opinion polling, the next step is to build a picture of what the traffic flow is believed to look like. An effective technique for clarifying the telecommunications structure as well as other operations of an organization in a more readily understandable form is the Structured Analysis and Design Technique (SADT).

The SADT system is an analysis method that allows one to describe an organizational structure at various levels of abstraction. It provides a framework for analysis and discussion of issues related to the functions of organizational components and their contribution to the overall effectiveness of the organization. While primarily used to define existing organizations, this model is well-suited to defining the way that an organization is expected to function. [Ref. 18]

Factors that require consideration in scenario building include anticipating growth rate of the demand

based on activities that will directly affect demand. Obviously, a communications provider would have an intuitive feeling that a catastrophic event will impact on the demand for a telecommunications service. While it may not be possible to predict when such an event will occur, he/she will want to be able to handle as much of the demand as can be handled optimally. This will very likely require estimating a level at which the demand may peak and balancing that level against the level at which demand is at its lowest point. It could mean considering the probability of each situation occuring and weighting those averages against a midpoint where supply and demand are believed to be in equilibrium. Its very hard to do and is essentially the basis for using the most effective forecasting tools available.

2. Application -- A Corporate Model

In 1977, a company called Teleglobe Canada began researching and developing a simulation model specifically for the purpose of offering the user a simple interactive means of walking through a scenario and evaluating the most probable impact. [Ref. 19: p. 37]. The study was designed to provide answers to the following questions:

(1) How are the company's costs linked to growth in the demand for telecommunications services?

(2) Are the operating costs, overhead expenses and capital costs consistent with levels of productivity and fair return on investment?

(3) What would be the impact on profits if the rates for service changed by 10%?

In addition to answering those questions and similar questions, there were three major objectives of the simulation model. First, the model was to generate a series of alternative scenarios and business plans based on a variety of assumptions related to internal company policies as well as external environmental circumstances. Second, the model was to identify the link between supply and demand

for a telecommunications service, socioeconomic variables and internal and external controllable variables. And finally, the model was designed to provide an indication of the corporations profitability as a function of a set of exogenous variables that are controllable to some extent since they involve internal policies. [Ref. 19: p. 38]

The basic premise of this model is that demand is determined by economic factors beyond the control of the company and that the company's provision of service is in reaction to the level of demand. The model calls for the development of a system of equations to explicitly relate demand, supply, elasticities and environmental factors. The quantification of the parameters would be expected to provide a measure of the impact of alternative policies. Figure 3.2 illustrates the concept. It is apparent from Figure 3.2 that operating revenues are derived from the demand module, while operating costs come from the module labelled supply. Operating income is derived by calculating the difference between supply and demand. By subtracting non-operating costs and revenues from operating income, the value of profit before taxes may be calculated.

The model is divided into three different phases that equate to different areas; demand, supply and economic analysis.

a. Demand Module -- Phase I

The Demand Module consists of the following submodules:

   (1) economic environment
   (2) prices and tariffs of services
   (3) demand
   (4) revenues

Two basic equations are found in this module. They are expressed as follows:

Economic
Environment
Module

Demand
Module

Supply
Module

Operating Revenues   Operating Cost

Financial Analysis
Module

Operating Income
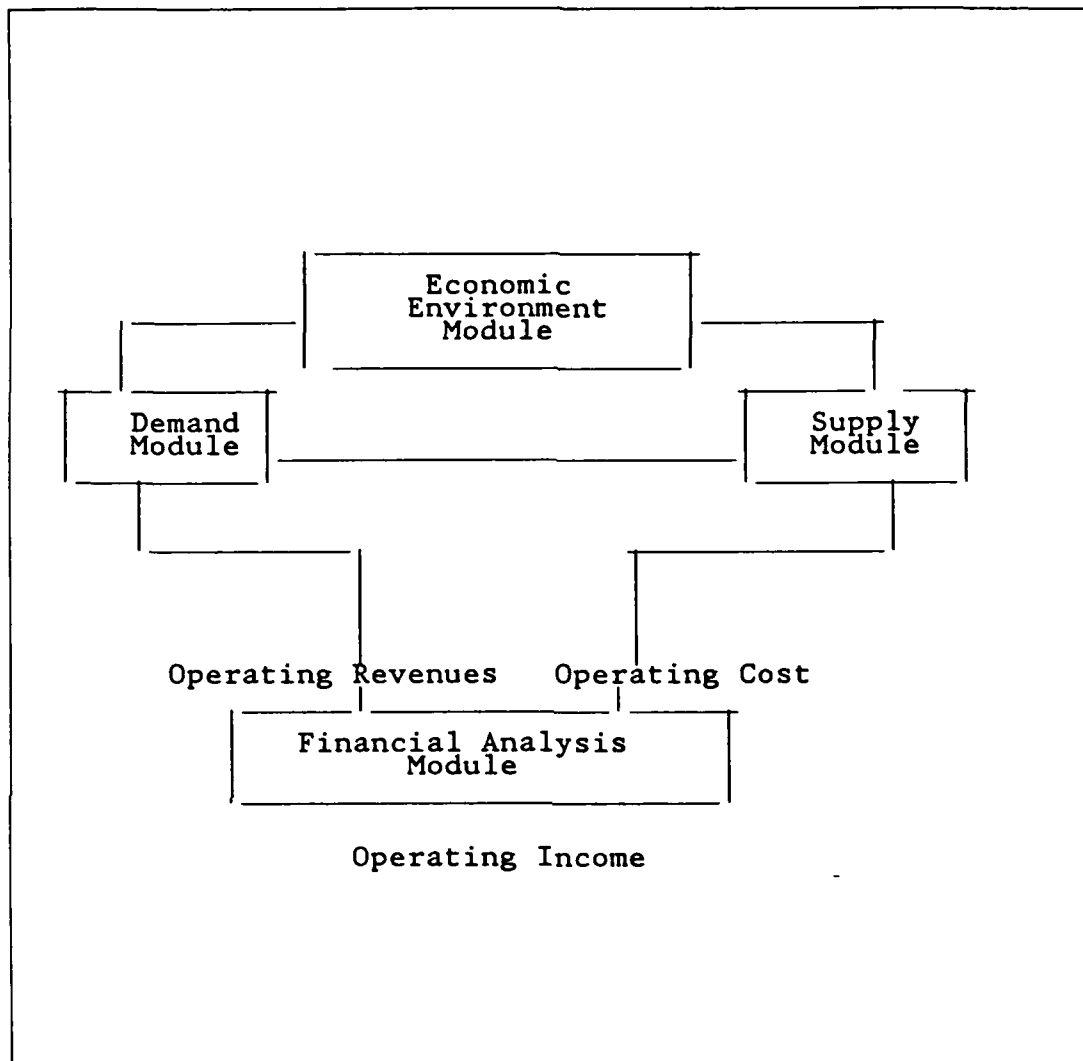
Figure 3.2   A Corporate Model -- Scenario Building.

Real Demand = F(Economic Environment, Price)   and

Revenue =   (Traffic x Tariff)

The real demand can generally be computed using an econo-
metric model, while the revenue equation would be defini-
tional.   Included   in   the   variable   called   economic
environment are such factors as income, trade, inflation,
immigration, habits, numbers of telephones installed, and

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costs of substitutes. The price variable is a weighted average of the weight charged to a user for a specific service. The tariff variable represents a weighted average of the rates over a sample of major countries where most of the telephone traffic with Canada either originates or terminates. Most of the data can be manipulated by the user in order to evaluate the impact of changes on the entire structure.

The simulation module is capable of putting out a report of the findings in either a standard format or a specialized form to meet a specific requirement.

       b. Supply Module -- Phase II

The supply module consists of the following components:

(1) capital outlays

(2) manpower expenses

(3) supply and expenses

       c. Comprehensive Module -- Phase III

This module provides a complete financial and economic analysis which uses the inputs and outputs of Phases I and II. It is worth noting that Phases I and II are independent in that they can be operated independently to provide only information specific to either demand or supply, respectively.

    3. User-Model Interactions

The Corporate Model is a computer program that directs the user through the operation in decision-tree style. Figure 3.3 shows a typical menu from which the user is invited to make selections. A completed interaction process has the effect of linking all of the variables in order to provide a report based on a given sequence of occurrences.

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Teleglobe Corporate Module

Explanation?

No   Yes

What Analysis?

| 1 LOOK UP | 2 TARIFF | 3 REV | 4 CAP EXP | 5 LABOR EXP | 6 MAT EXP | 7 FIN ANAL | ... |

What level?

| 1 GLOBAL | 2 SERVICE | 3 COUNTRY |

Scenario   Look Up

| 1 ECONOMICS | 2 TRAFFIC | 3 CAPITAL | 4 LABOR | ... |

Scenario Completed?

No   Yes

What Report?

| 1 TRAFFIC | 2 REV | 3 CAP EXP | 4 LAB EXP | 5 MAT EXP | 6 INCOME STMNT | ... |

Report

Code
CAP EXP = Capital Expense
LAB EXP = Labor Expense
MAT EXP = Material Expense
REV   = Revenue
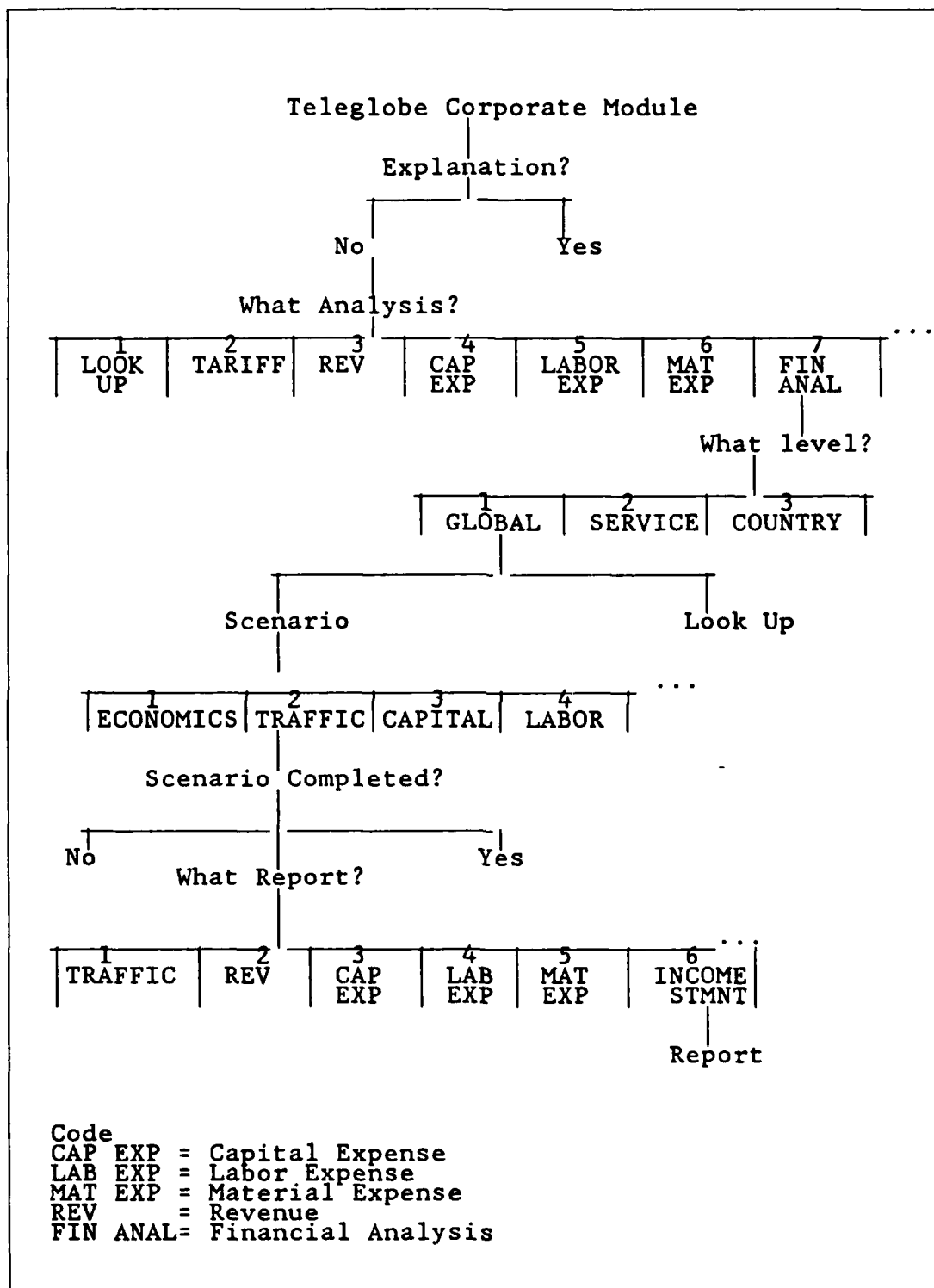FIN ANAL= Financial Analysis

Figure 3.3   User's Interactive Options.

4. Strengths and Weaknesses

a. Strengths

One very important strength from a user's perspective is the relative simplicity of the model. The user is provided with an instructive program that makes it possible for technicians as well as managers to walk-through with explanations of variables if needed. Another advantage is that the final report is in the form of a straight-forward readout that involves an an easily interpreted output of the results. The programming language was purposely selected to be one that can easily be modified by the users. And finally, the major strength of any forecasting model is in its ability to predict. In this particular model, the authors claim an error rate of less than three percent per year. [Ref. 19: p. 42]

b. Weaknessess

One major weakness with any model of this form is the difficulty in accounting for all contingencies. There is no way to program for an unprecedented event unless there is some form of artificial intelligence incorporated into the program, which doesn't appear to be the case. In any model where there is an attempt to quantify human behaviors that are not measurable, there are bound to be problems of consistency. The results may rely too heavily upon the judgment of the programmers.

J. USAGE FORECASTING

One way to estimate demand for a telecommunications service is to empirically determine the number of users who wish to communicate with other users by becoming network subscribers. Another way to assess demand is to examine usage. In the former situation, the would-be subscriber wishes to gain access to telephone lines, while in the latter situation, the user has access to the lines and now wishes to use the system to make calls (or receive calls). [Ref. 20: p. 3]

The usage rate is the amount of telephone traffic originated or terminated by each customer at a given exchange during the busy hour [Ref. 21: P. 37]. The unit of measure is the Erlang.[1] Traffic may be defined as:

$$A = nh/T$$

Where A is the telephone traffic in Erlangs, n represents the number of calls originating during time T and h is defined as the average call duration or holding time. [Ref. 22]

When usage forecasting is done, the forecaster may be concerned with any or all of the following factors:

(1) customer classification

(2) holding time

(3) congestion

(4) call set up

(5) traffic category (local or long distance)

Customer classification very often refers to residential versus business customers. There is little doubt that the prime time (from the industry's perspective) for call placement and normal operating hours for most business are purposely linked. Businesses, in general, generate a great deal more profit for the telephone industry than do residential customers. The industry would probably like to control the flow of traffic so that there is near-congestion around the clock. Because the philosophy behind placing telephone calls differs between business customers and residential customers, there are probably two primary calling patterns that vary by the time of day. The high cost of placing a call during the day, when most businesses are doing business, is designed to keep the congestion manageable. Conversely, the lower cost of placing a call during the evening or night time is designed to increase the level of

---

[1]The usage variable used in the United States is one hundred call second per main station (CCS/M). One CCS is equivalent to 1/36 Erlang.

demand on the system in order to reduce the cost of operating the system with the overhead required during the day. The problem is that business calling is less elastic than residential calling. For those reasons, most studies concentrate on either one group of user or the other because it is too difficult to attempt to sort out all of the variables when trying to aggregate all users in estimating demand.

Holding time refers to the period of a call from the time a connection has been made until a disconnect takes place. This period is distinguished from the call set-up time during which a customer waits for the connection to be successfully accomplished.

Traffic category is concerned with the destination of the call. Whether a call is a local or toll call, within the same exchange or long distance. Forecasters may differentiate between the categories in order to achieve greater accuracy in formulating the demand function.

1. Measuring Usage

Usage forecasting is actually easier to implement than most of the access models simply because the technology to measure usage is available. This means that predicting demand for use of a telecommunications system may be easier than forecasting the demand for access to the lines since predicting the demand for access is still mostly empirically determined.[2] The technology currently used to measure traffic flow may be selected on the basis of traffic parameters of interest to the forecaster. Since traffic measuring equipment is expensive, the forecaster has to be especially careful in selecting his data. Some of the specifications may include the ability to measure traffic dispersion (source/destination data), mean holding time as well as the

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[2]Easier should not be equated with greater accuracy in the context of this discussion.

distribution of individual holding time of equipment. [Ref. 23: p. 651]

Equipment for measuring usage can be placed in two categories. The first category consists of portable equipment used to go from site-to-site, while the second group is equipment that is permanently installed at the exchanges [Ref. 23: p. 651]. There are some advantages to using portable equipment:

(1) Since the equipment can be transported, there is a cost savings as a result of sharing resources

(2) Because the equipment is not permanently installed, it is easier to modify, service or replace

One major disadvantage with using portable equipment is that the data collected at a random site may not be as representative of the true level of usage since there is likely to be fewer data points to use in constructing a graph depicting the level of use.

Increasingly, however, forecasters are taking advantage of computer technology that makes it possible to gather volumes of data on traffic flow on trunk lines by monitoring permanently installed traffic metering systems. Three popular data of interest are holding times, traffic intensity and traffic dispersion. The type of equipment used to take the measurements will be as varied as the vendors available to provide the equipment.

In forecasting the demand for telephone service in Papua, New Guinea, holding time was measured by using a electromagnetic counter attached to a simple timing circuit. The simplicity of the equipment made the bookkeeping a cumbersome process. [Ref. 23: p. 534]

Measuring traffic intensity requires collecting a cross section of data for the entire network. A device called an electronic erlang-hour meter (EEHM) was used to measure the volume of traffic of an analog signal from a system of connected leads. Figure 3.4 represents a

functional model of the equipment used in the New Guinea study. Output from the mechanism took the form of DC pulses which equated to 0.1 erlang hour. For erlang-hours in the 5 to 500 range, the error was better than + 1.5% [Ref. 23: p. 652].

For determining traffic dispersion, that is origin and destination data, the study called for a modified version of call-dispersion equipment used in billing inquiries. The device provided an approximation. However, more sophisticated equipment specifically designed to meet the requirement is available and its usefulness is described in the section entitled "Matrix Forecasting".

Once sufficient traffic measurement data has been accumulated, it is possible to graph the data points to determine patterns of use. Any time series analysis could be applied and will yield varying degrees of forecasting accuracy depending upon the specific model selected and the fit of the data.

K. MATRIX FORECASTING
   1. Description
      This form of predicting future demand is built around a table of traffic from sources to destinations called a matrix. The traffic dispersion matrix is designed to describe the flow of traffic in a communications network by defining the ingoing and outgoing communications between all exchanges in the network. [Ref. 24: p. 35]. The system is generated by taking the total traffic originating from an exhange and distributing the traffic along each row of the matrix prescribed by the measured dispersion. The matrix meets the descriptive criteria of Erlangs and direction with respect to traffic. [Ref. 24]

      Due to dimensional limitations, time can not be represented by a single matrix; instead, the matrix is designed to illustrate the flow of traffic in a single
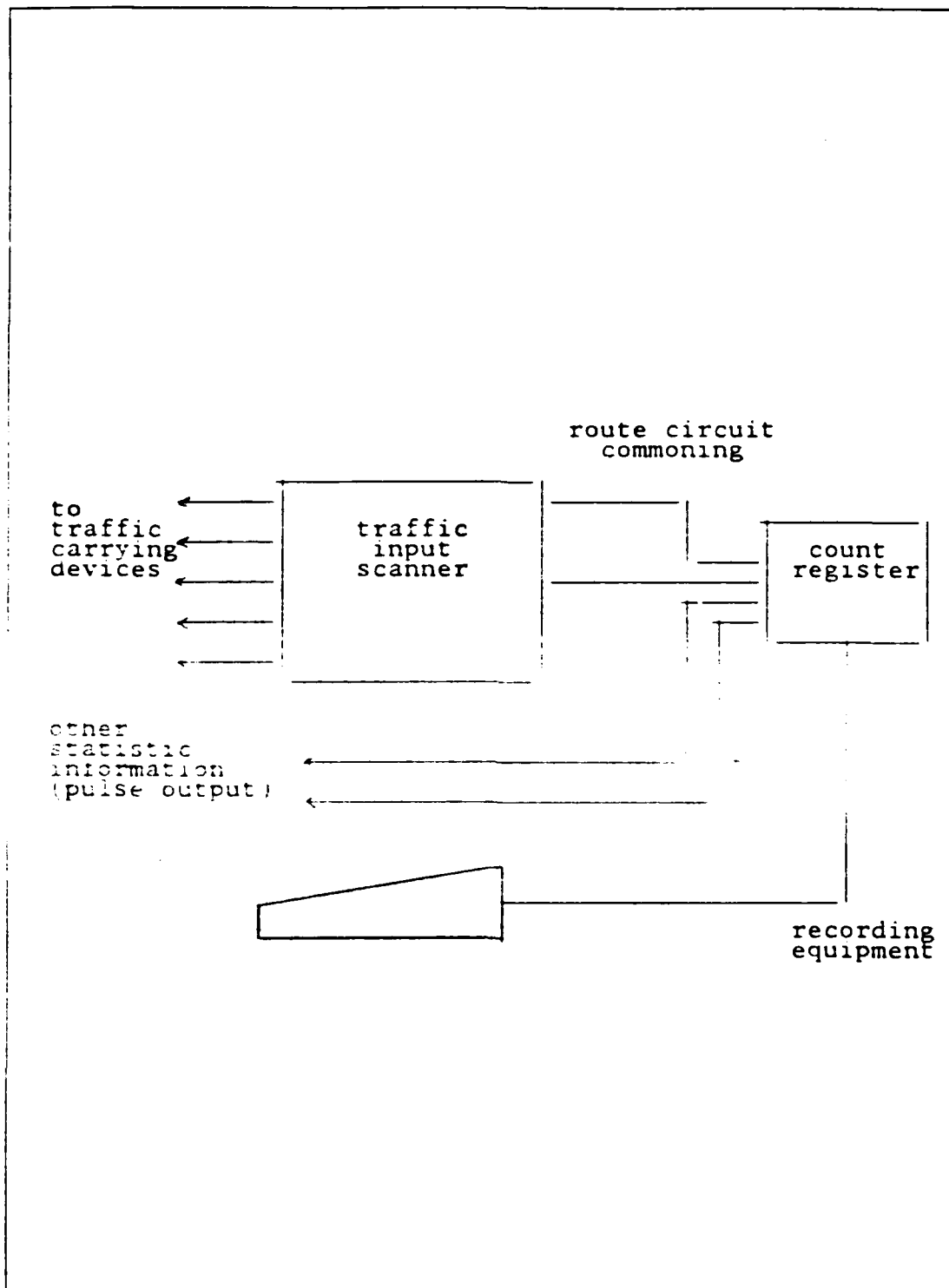
Figure 3.4   Model of Traffic Measuring System.

instant of time. Figure 3.5 provides an illustration of the
basic matrix. Therefore, in order to fully represent what
is happening through time, an array consisting of all of the
connections between all exchanges for each period of time
must be created.

Figure 3.5   Traffic Dispersion Matrix.

[Ref. 24] provides a series of basic steps to be undertaken
in producing a forecast matrix. Initially, a base matrix
must be generated. The base matrix in the model is the

matrix which reflects the most current values of the traffic measured. Usually, the matrix is constructed from the dispersion measurements as well as the total originated traffic measurements. The entire process continues throughout the period and involves maintaining a data base with the updated dispersion readings.

Next, the author calls for growing the matrix. This is the process that is actually used for preparing the forecasts. Forecasting is done by multiplying each element of the base matrix by a composite growth factor. The growth factor is derived by considering growth in traffic at both the source and destination. There is no standard equation for computing the growth factor. Therefore, the inputs are often subjectively determined. The resulting matrix contains more traffic than the original matrix and has different dispersion measurements for each row.

Balancing the matrix is the final step. This process refers to using the Kruithof Double Factor method of balancing row and column totals against separately derived targeted values. This technique calls for imposing the increased reliability of the macro estimates of the traffic upon the micro estimates. [Ref. 24: p. 37]

2. Application -- Victoria Australia

Engineering and commercial personnel in Victoria, Australia were and are concerned with forecasting accuracy as it pertains to the ability of its switching and transmission equipment to handle the flow of traffic, particularly in the future. Their concerns are much like the concerns of of telecommunications service industry personnel everywhere. Overforecasting results in the installation of too much equipment which creates a suboptimal operation and underforecasting manifests itself in congestion and substandard grade-of-service which may ultimately lead to loss of revenue due to customer dissatisfaction.

In using a matrix forecasting model, headquarters of Telecomm Australia developed an algorithm to produce a set of macro forecasts for call hours and traffic. The agreed set of macros became the official target for commercial forecasts. Once a forecast has been generated, the accuracy must then be assessed.

One aspect of the quality control system is an empirical technique based on the assumption that each year's forecast of the traffic at a given point in time will be the same quantity. Successive forecasts are simply compared in the matrix element-by-element. The difference between successive forecasts are expressed as the root mean square error. [Ref. 24: p. 38]

Another aspect of the monitoring system compares existing traffic dispersions with new readings. Algorithms are designed to flag only significant differences. Still another component in use is a so-called Traffic Trend Analysis System (TTAS) which examines weekly traffic measurements and reports significant variations from historical data trends. The system employs a standard decomposition technique to generate a mathematical model of the traffic behavior. As new data is generated, a comparison is made, again flagging the discrepancies only. [Ref. 24: p. 38]

3. Model Strengths and Weaknesses

The potential for the Matrix Forecasting Model is great. Computer technology has made forecasting the flow of traffic an almost totally automatic process. Good or bad, there is still an empirical flavor to this method. A judgment must be made by the forecaster in determining what macros will be used for comparison purposes. Although it is difficult to judge the total system, it is highly probable that the forecasts are as reliable as any other model that eventually calls for the use of time-series and econometric models in its forecasting requirements.

L. BOX-JENKINS MODEL

This whole class of models was developed by Box and Jenkins for the purpose of exploiting what was often noted in the analysis of time series data as the dependency of successive observations. The basic premise here is that successive observations in a time series are dependent because they are determined by the same previous realizations of the variable. As mentioned in Chapter II, the Box-Jenkins technique takes time series data and mathematically fits the data such that smaller errors are assigned to history. It is most appropriate to use this technique for short term forecasting where this method is ranked very high in terms of its accuracy and reliability.

This class of models are relatively complexed and before one can understand how the models function, it may help to understand some of the underlying concepts.

1. Description of the Modeling Process

The Box-Jenkins models are based on autoregressive integrated moving average (ARIMA) time series models. The model is built up with the assistance of summary statistics from the available data. One of the summary statistics is the observed data's autocorrelation function (acf) which is the correlation of the data with itself at time lags 1, 2, 3,...n. [Ref. 25: p. 132]. The focus of the Box-Jenkins Models is to be able to identify patterns in the statistics. The three step iterative process involves identification, estimation and diagnostic checking.

a. Identification

If through the initial analysis the time series appears to have no mean (nonstationary)[3] then the first difference should be examined. The differencing may suggest

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[3]See Appendix A for a glossary of terms related to Box-Jenkins Models.

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a regression without clearly identifying the number of time periods (lags) separating the correlations. This may call for a partial autocorrelation for the first difference series. Perhaps now a more clearly defined regression will then be identified.

b. Estimation

Assuming now that a model has been identified, the next step is to estimate the parameters. This is simply estimating the standard error of the coefficients, usually by a linear least squares process.

c. Diagnostic Checking

The procedure now calls for diagnostic checking, that is, examining the estimated errors. If the fitted model is adequate it should be capable of transforming the observations to a white noise process. [Ref. 26: p. 211]. Next, it is necessary to compute the residuals. If the model is appropriate, then the autocorrelations should not differ significantly from zero. If the residual autocorrelations are nonzero, the entire procedure must be repeated. The process is repeated until the residual autocorrelations resemble a white noise process. [Ref. 38: p. 212]. Once the model passes diagnostic checking, it may be translated into a model for forecasting. Additional terminology as it relates to the Box-Jenkins series of models is provided in Appendix A.

2. Applications

This section covers the results of two studies that examined the models for their appropriateness in forecasting usage demand. One study was on the French telecommunications network, conducted by Passeron and Eteve in 1981. The second study was carried out by AT&T Bell Laboratories also in 1981.

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a. French Telecommunications Network Study

A study of the French telephone network provided an interesting comparison of the Holt-Winters and Box-Jenkins (univariate) models for forecasting [Ref. 27]. The French long distance telephone network used the data collected during a five-day period measured during the busy hour and used the second highest value among the five as a monthly representative value (MRV). Repeating this process every month, a yearly representative value (YRV) was similarly chosen, the second highest value among the 12 month values. For the French study, the French Riviera subnetwork was selected for the comparison of the Holt-Winters and Box-Jenkins methods. The analysis of sixty MRVs was conducted. The techniques both called for aggregating the traffic flow in order to obtain significant data. Two cases were considered. The first involve traffic flows from each exchange of the subnetwork to the total French network. The second case utilized the traffic dispersion matrix using the Kruithof method. Figure 3.6 illustrates the procedure [Ref. 31: p. 3]

Graphical plotting of the collected data and subjecting them to time series analysis revealed three classes of the model. The three categories, types a, b and c are illustrated below. In figure 3.7, type a, the outgoing traffic for the Saint-Maxime depicts a slight increasing trend with a significant seasonal component. Figure 3.8, type b, shows that outgoing traffic flow from Nice clearly is indicative of an increasing trend on a seasonal pattern. And finally, in figure 3.9, type c, the outgoing traffic appears to be increasing sharply, but shows only a slight seasonal variation. The trends all appear to be linear.

The apparent seasonal variation that was implied by the graphical analysis leads to the selection of the

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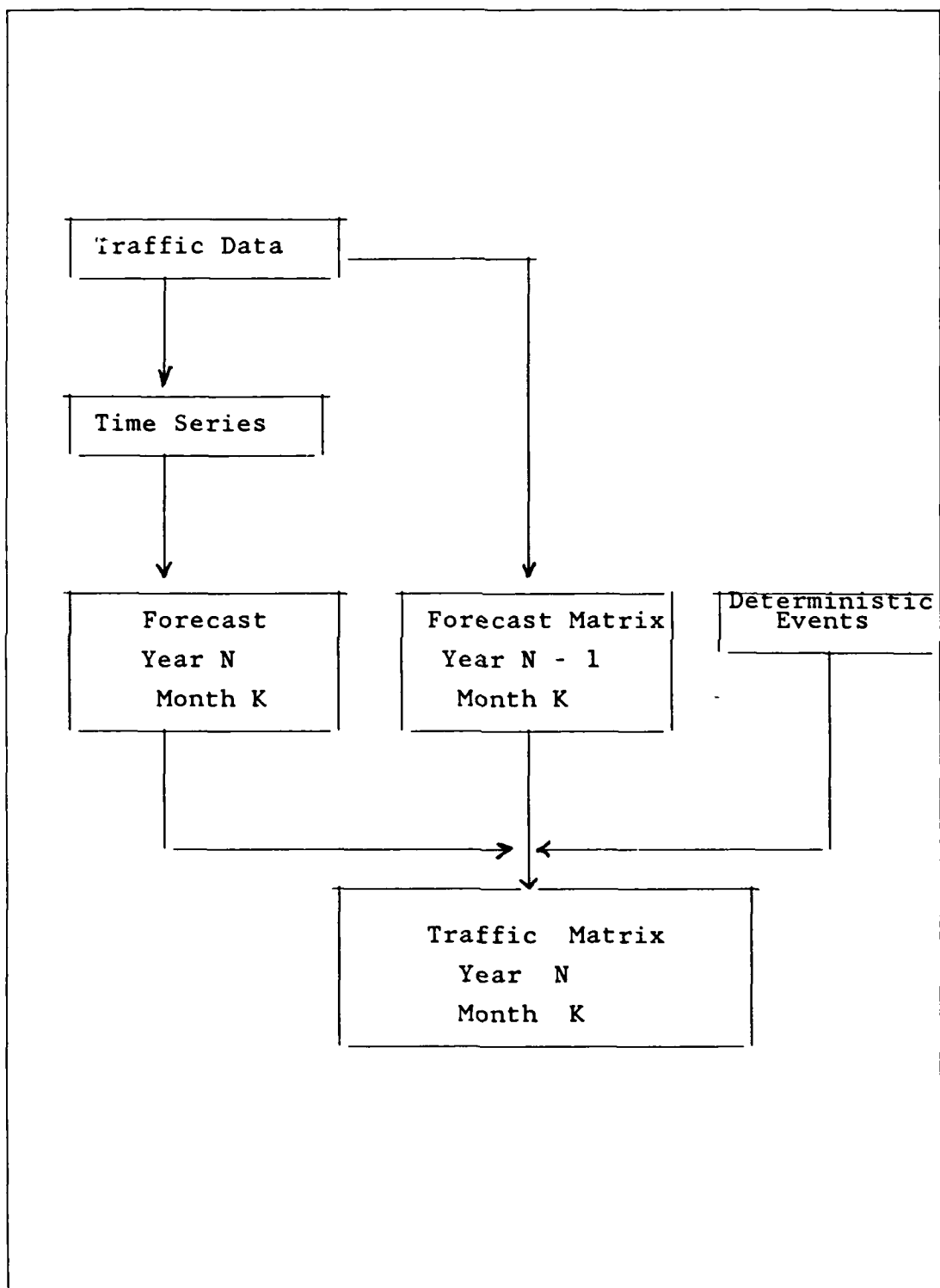
Figure 3.6   French Traffic Flow Measurement.
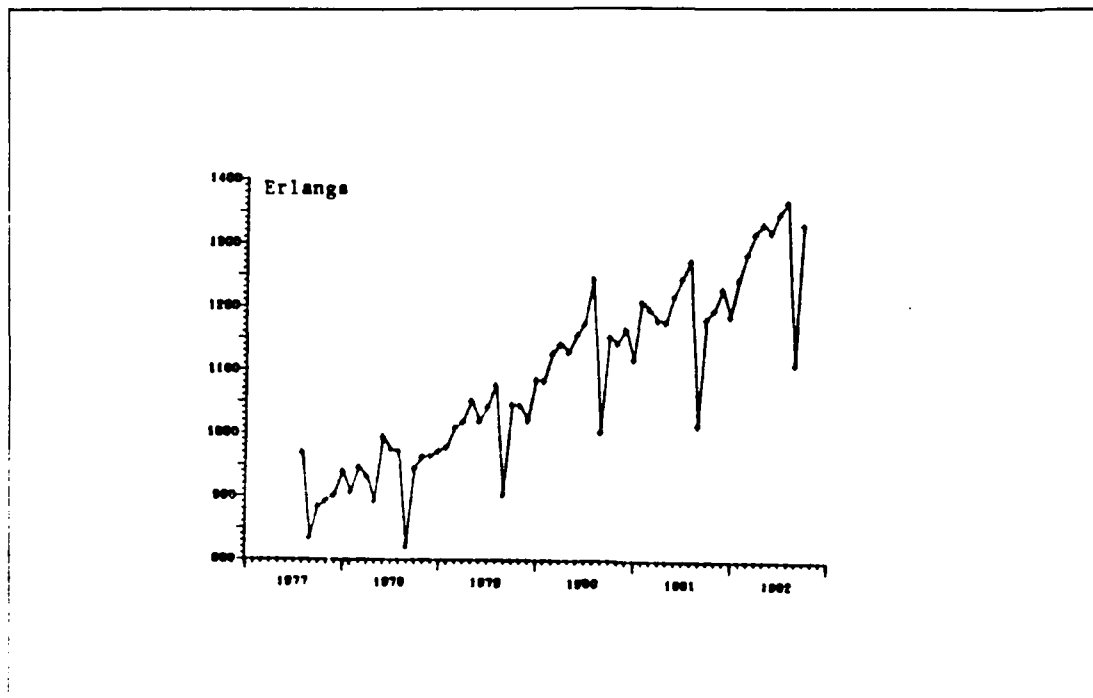
Figure 3.7   Saint-Maxime (outgoing traffic).

Holt-Winters and Box-Jenkins methods for forecasting future
behavior.

In the 1981 study of the French communicating
system, a minimum of sixty-six observations were required to
fit a seasonal model with a degree of confidence, while the
experimenters only had sixty data points. Through analysis
of the graphs derived, the team of Passeron and Eteve deter-
mined that the best fit of the data could be obtained
through a logarithm transformation. The following general
equation forms were used for all of the series presented:

$$w_t = (1- \beta)^d x_t{}^\gamma \qquad \text{(eqn 3.13)}$$

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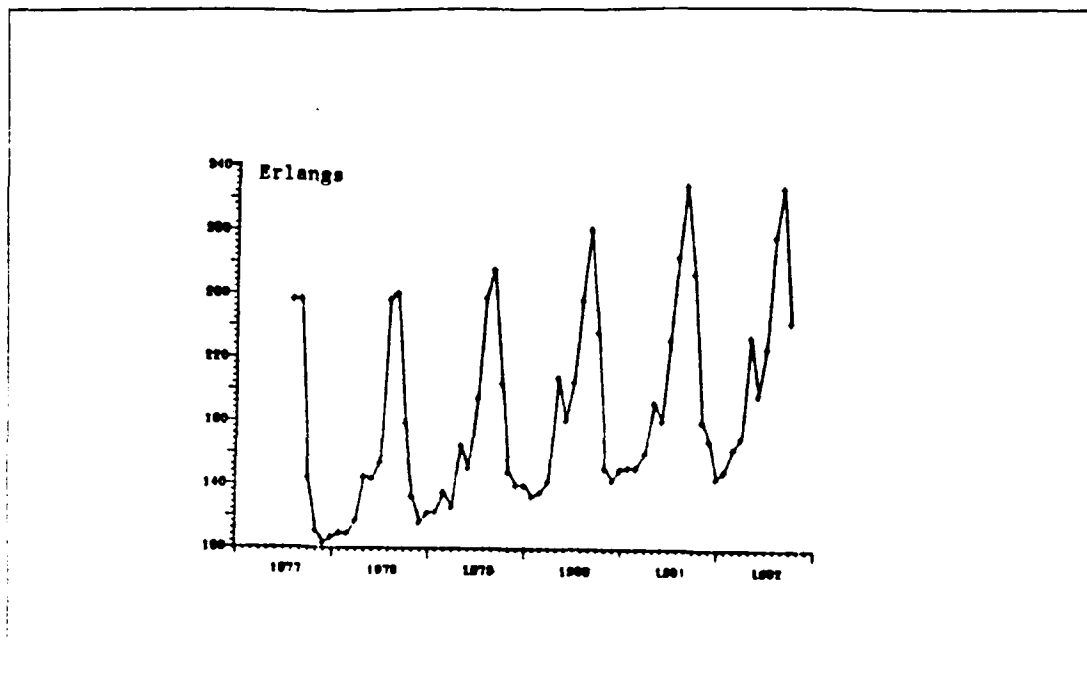
Figure 3.8   Nice outgoing traffic.

$$(1 - \theta_1 B - \ldots - \theta_p B^p)(w_t - C) \qquad \text{(eqn 3.14)}$$

$$= (1- \theta_1 \beta - \ldots - \theta_q \beta^p) \, a_t$$

$$(1-\theta_1 B - \ldots - \theta_p B^p)(1-\theta_{1s} B^s - \ldots \theta_{ps} B^{ps}) \qquad \text{(eqn 3.15)}$$

$$(1-B)^d (1-B^s)^{ds} X\lambda_t - C$$
$$= (1-\theta_1 B - \ldots - \theta_q B^q)(1- \theta_{1s} B_s - \ldots - \theta_{qs} B^{qs}) \, a_t$$

Where equation 3.13 expresses a stationary representation, equation 3.14 is useful in explaining the mixed autoregressive moving average and equation 3.15 is a useful form for the seasonal time series with period s.

The team found that differencing was necessary in order to handle the nonstationarity. After several iterations, they proposed the following model forms:

(a) For series of type (b), a moving average model of the first order, MA(1)
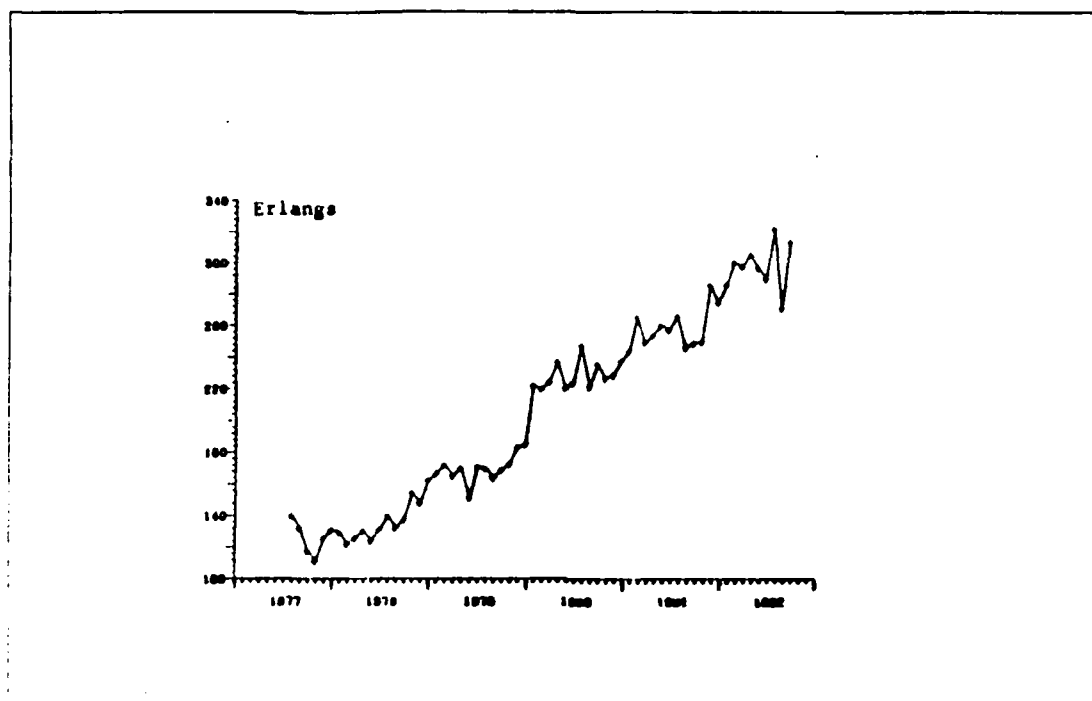
Figure 3.9   Menton (outgoing traffic).

    b)   For series of types (a) and (c), MA(1), autoregres-
         sive (AR) and the combination autoregressive moving
         average (ARMA) was useful, whether or not a seasonal
         coefficient was noted.

[Ref. 28: p. 4]

        b. AT&T Bell Laboratories Study

            In the AT&T study, the procedure previously
described was implemented using 35 CCS/M[4] time series data
for the period between May 1969 and April 1975 and 300
simulated realizations. [Ref. 29: p. 828]. Bell operating
companies (BOCs) define the average busy season (ABS) as the
average of the highest three observations in a year. This
ABS is the quantity used to measure forecast accuracy, which
is the percent difference between a forecast and the actual
quantity. Forecasting models were fitted to the data. From
that, forecasts were generated for 24 months and converted

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[4]CCS/M equals one hundred call seconds per main station.

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TABLE IV

BOX-JENKINS COMPARATIVE DATA

Series	Type	Model Error (%)
Saint-Maxime	a	4.6
Nice	b	1.7
towards Paris	b	4.3
towards Amiens	b	7.8
Menton	c	4.0
Draguignan	c	2.6

to ABS values. The percent error was then calculated. The initial model was defined as

$$x_t = (1 - \beta^{12})z_t \qquad \text{(eqn 3.16)}$$

Since x_t was not a white noise process, another iteration wa require. The next model considered was

$$(1 - \varphi \beta)x_t = (1 - \theta \beta^{12})a_t \qquad \text{(eqn 3.17)}$$

After estimation, it became

$$(1-0.63B)(1-B^{12})z_t = (1-0.47B^{12})a_t \qquad \text{(eqn 3.18)}$$

Where $\sigma_a = 0.12$ and $Q = x^2 (34) = 18.0$. After examining the residuals of the autocorrelation function, it was determined that no further iterations were necessary. Additionally, alternative ARMA models were investigated in an effort to understand the impact of overfitting,

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underfitting, differencing and modeling a spurious trend on the forecast. [Ref. 29: p. 830]. A second form was subjected to the identification, estimation and diagnostic checking process. The second model resulted in the following equation:

$$(1-0.16B)(1-B^{12})z_t = (1+0.05B)(1-.047B^{12})a_t \quad \text{(eqn 3.19)}$$

Where $\sigma_a = 0.12$, and $Q = 19.0$. While neither model indicated inadequacy from the perspective of the fitting, the forecasts obtained were significantly different. When the models were used for forecasting, the original model was more conservative in its extrapolations. [Ref. 29: p. 835].

3. Model Strengths and Weakness

    a. Strengths

        In general, the Box-Jenkins model are among the most accurate, especially for forecasting short-ranged data. Like all trend exptrapolation models, the accuracy of the models begin to erode as the forecast gets further away from the historical data. Because of its reliability and accuracy in forecasting short-ranged information, it is well-suited to the usage forecasting in assessing the likely busy hour and busy seasons. The process can and is usually performed through the use of computer software.

    b. Weaknesses

        Box-Jenkins models require a great deal of historical data. Therefore, it is not well-suited for use with a new organization unless cross-section data analysis is performed. Another disadvantage is that the models require a lot of judgment by the forecaster in being able to determine the autocorrelation function. This could result in a different forecast using the same data if done by another forecaster. And while computer software is available to perform the estimations, the CPU time involved in

executing the program is considered to be relatively expensive. Probably the biggest disadvantage is the complexity of the model. From a user's standpoint, this would represent a major obstacle in selecting the model because there is so much difficulty in just interpreting the results.

M. HOLT-WINTERS METHOD

1. Description

A form of sophisticated exponential smoothing, the Holt-Winters method is noted for its effectiveness in handling both trend and seasonal subpatterns in data. Exponential smoothing, the reader will recall, is a technique used to "correct" the data by applying a term called a smoothing constant which makes the equation of a curve fit the historical data. The smoothing constant is a number between zero and one. The ranges for the smoothing constant will vary depending upon the specific nature of the demand to be forecast. The general rule in assigning weight to the constant is that more weight is placed on the most recent data. [Ref. 30: p. 231]. The technique is fully automatic and requires very little interaction on the part of the forecaster.

2. Applications

This particular method was selected in the study of the French network in order to emphasize the seasonal component of the traffic data. The method assumes that an observation noted at time x, represented by x_t can be expressed by the following:

$$x_t = \text{(local mean)} \; X \; \text{(seasonal factor)} + \text{error} \quad \text{(eqn 3.20)}$$

Where X may be either an additive model (+) or a multiplicative model (x). The local mean calls for using the additive or multiplicative term whenever the logarithms of the data

are used. Additionally, the model assumes that the additive error has a constant variance. [Ref. 31: p. 7]

Analysis with the Holt-Winters method requires only two or three years of data. Older data could be discarded when they preceded a change in structure. Three exponential smoothing constants, α, β, and γ were used to update components after initialization as new information became available. α was used for the seasonal factor, while β was used for the local mean and γ for the trend. In terms of its usefulness, this procedure was good for forecasting a maximum of six months forward. [Ref. 31: p. 4]

The following equations were used in updating noted trends for the additive case:

$$m_t = \alpha \ (x_t - F_{t-1}) + (1 - \alpha) \ (m_{t-1} + (r_{t-1})$$

$$F_t = \beta \ (x_t - m_t) + (1 - \beta) \ F_{t-s}$$

$$r_t = \gamma \ (m_t - m_{t-1}) + (1 - \gamma) \ r_{t-1}$$

Forecasting n steps forward may be done using:

$$x \ (t, n) = m_t + nr_t + F_{t-s+n}$$

Where m_t = estimate of the deseasonalized mean level at time t

> F_t = estimated seasonal factor at time t
> r_t = estimated trend term at time t
> s   = periodicity of the time series (s=12 for
>   monthly data)

Whenever a linear trend was noted, the Holt-Winters method was applied; first with a multiplicative seasonal component and then with an additive one. Using the criterion of minimum average absolute deviation, the additive model was generally more accurate.

Estimating is best accomplished through computer programs available on the market. Such programs compare

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many values and retain the best of these on the basis of average absolute error between the raw series and the fitted series. [Ref. 31: p. 4]. Table V summarizes the results.

TABLE V
HOLT-WINTERS COMPARATIVE DATA

Series	Type	Model Error (%)
Saint-Maxime	a	8.5
Nice	b	2.2
towards Paris	b	4.4
towards Amiens	b	8.0
Menton	c	4.9
Draguignan	c	2.7

3. Model Strengths and Weaknesses

   a. Strengths

   The major strength of this model is in its ability to handle trend and seasonality in the data. Among other strengths of the Holt-Winters Model is the simplicity in implementation. Completely automatic, the program requires very little of the forecaster. The results (output) is straightforward and easy to understand.

   In terms of accuracy, the model is generally more accurate than other exponential smoothing techniques. And, although frequently compared to the Box-Jenkins for reliability in short-ranged forecasting, it is still considered to be slightly inferior, particularly as the time horizon increases. One consideration that should be taken into account is the relative cost. In comparison to Box-Jenkins, the CPU time is used more efficiently for the

Holt-Winters Model. Moreover, because the data requirements are small, it takes less computer storage capacity to run the software. Holt-Winters is considered to be a very robust, highly adaptive model since it is constantly updating the components as new information is added to the data base.

      b. Weaknesses

          Like most exponential smoothing techniques, it is not useful for predicting turning points. Another disadvantage is that it is limited to short-ranged and medium-ranged forecasting. Beyond those ranges, the accuracy erodes sharply. From the user's perspective, there may be the problem of selecting the right smoothing constant.

IV. FORECASTING DEMAND FOR TELECOMMUNICATIONS IN THE U.S. NAVY

A. BACKGROUND

Having secure, reliable, accurate and timely end-to-end communications is a most essential element in keeping the United States Navy operationally ready to carry out its worldwide mission. We are technologically advanced to the point where the Captain on the bridge can talk directly from on station to his Commander-In-Chief. This reality has changed the nature of Command and Control Communications. Moreover, technology has made it so easy to transmit information that we very often find that we are saturated with information that must be analyzed and frequently incorporated into the plan-of-the-day. However, we are also finding that much of the information may not need to be passed electronically, but may be deliverable via the postal system or at the next port-of-call. The problem is congestion of our communications links.

The United States Navy communicates in several ways. Among the many are High Frequency (HF) tactical communications, Fleet Broadcast System, secure voice, Automated Voice Network (AUTOVON), Automated Secure Voice Communications (AUTOSEVOCOM), Automated Digital Network (AUTODIN), UHF Satellite Communications, Naval Communications and Processing System (NAVCOMPARS) and commercial communications. Although it is conceivable that a model for assessing demand for telecommunications services by the Navy is within the realm of possibility, it would require a full-blown study in its own right. A more manageable scheme here examines a small segment of the Naval Telecommunications System (NTS). This section focuses on the demand for Navy message telecommunications service, specifically through the NAVCOMPARS and AUTODIN systems.

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Following a description of AUTODIN and NAVCOMPARS, this chapter will examine the reason that it is necessary to assess the demand for message communications services--the congestion issue. That segment will be followed by a look at the determinants of demand for telecommunications service by the Navy in general and will then focus on the determinants for message processing services. Following that will be an analysis of the appropriateness of employing any of the models presented in the previous chapter for adaptation to use by the Navy.

B. AUTODIN

Automated Digital Network (AUTODIN) is a worldwide, high speed common user Data Communications System operated for and managed by the Defense Communications Agency (DCA). [Ref. 32: p. 1]

1. Description of AUTODIN

The system which provides the capability to communicate both secure teletype and secure data was initially activated in the early 1960s as a replacement system for a number of manual networks that were in existence. The original five AUTODIN Switching Centers (ASCs) and their associated tributary terminals has expanded to nine ASCs in the continental United States (CONUS) and another six in overseas locations. Each CONUS ASC is capable of supporting up to 300 tributary terminals, while another 100 to 200 are being supported by each overseas facility.[5] [Ref. 32: p. 2]

2. Message Switching

The message switching units located at each ASC employ a store-and-forward delivery technique using an algorithm based on the precedence of the traffic and the traffic load on the network. A store-and-forward message

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[5]A list of the ASCs may be found in Appendix B.

switching system is a system that does not require the presence of the user on the receiving end of the link. However, the entire message must be received by each intermediate node before the message can be forwarded to the next node along the path. The path taken by each message is a fixed route predetermined by the format and routing indicators used in the message header. [Ref. 33: p. 208]

3. System Characteristics

a. Security

AUTODIN's transmission security is reasonably assured through its utilization of a link encryption technique that encrypts every transmission online as it enters the system. At the receiving terminal, the signal is decrypted. All traffic, regardless of security classification, is treated in the same fashion. And to further ensure that changes in the level of operational activity are not compromised by the system, a continuous encryption keystream is passed over all links.

b. System Capabilities

AUTODIN provides its subscribers with the automatic capability to communicate with other users in the system and is connected to other systems which operate in compatible modes such as computer, punched card, paper tape and magnetic tape. The computer at the ASC automatically converts the bits to the appropriate media and speed for the terminal equipment of the destination addressee(s). [Ref. 32: p. 3]

c. Error Detection and Reliability

The AUTODIN system automatically detects and corrects messages. The system examines message headings for proper format, content and information needed to ensure correct routing and delivery. Message endings are screened to ensure that the message has been received in its entirety. Messages that are improperly formatted in any way

are rejected by the system for manual analysis and correction. [Ref. 32: p. 4]. The Navy is able to interface with AUTODIN through its NAVCOMPARS and LDMX equipment.

C. NAVY MESSAGE PROCESSING SYSTEMS

Even though the AUTODIN system was brought on line in the early 1960s, it wasn't until the early 1970s that the United States Navy began working with new automated message processing systems. In December 1971, the first Local Digital Message Exchange (LDMX) was installed at OPNAV TCC. One and one-half years later, NAVCAMS LANT received the first Naval Communications Processing and Routing System (NAVCOMPARS).

1. NAVCOMPARS

The Naval Communications Processing and Routing System is the Navy's baseline message processing system of the NTS. The system interfaces with the AUTODIN system primarily to provide communications support to the fleet through its interfaces with Common User Digital Information Exchange (CUDIX), ORESTES and TSSIX. Although chiefly responsible for supporting operational forces afloat, NAVCOMPARS also provides Over-The-Counter (OTC) Delivery to tenant commands and serves other remote subscribers to the system. [Ref. 34: p. 1-2]. There are five NAVCOMMPARS sites operational worldwide. They are listed in Appendix C.

2. LDMX

The Local Digital Message Exchange is a system designed to automate the message handling procedures at major Naval Telecommunications Centers (NTCC). The primary mission is to provide OTC service to local commands and other remote subscribers to the system. Also interfaced with the AUTODIN system via DCS, the LDMX's functions include message processing, routing, formatting, validation, internal distribution assignment, editing, readressing, files, retrieval and statistical report generation. Remote

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subscriber with insufficient justification warranting LDMX equipment are served by Remote Information Exchange Terminal (RIXT) which extends the electronic capabilities of a host LDMX or NAVCOMPARS system located in the same geographic region. [Ref. 34: p. 1-1]

   3.   Computer Systems

        Two mainframe computer systems are used to operate the NAVCOMPARS and LDMX systems. The Central Processing Units (CPU) are the Univac U90/60 and U70/45 series. The U90/60 is a high performance data processor capable of communications suitable for real-time Command and Control operations. The processor consists of semiconductor memory units, program control and arithmetic units, and input/ output control processor. Each CPU has a 1.5 megabyte main memory storage capacity.

        The U70/45 is a solid state digital processor also capable of handling real-time communications. Its CPU is made up of magnetic core memory units, program control and arithmetic units and input/output control. The system's modular main memory has a storage capacity of 512 kilobytes. The goal of the Navy is to upgrade from the U70/45 to the U90/60. [Ref. 34: p. 1-3]

D. COPING WITH CONGESTION

        To illustrate the concept of congestion, a telephone system provides the clearest example. Anyone who has ever dialed up an AUTOVON number and gotten a rapid (120 pulses per second) beeping signal has experienced blocking. Not to be confused with a busy signal (60 pulses per second) which indicates that the number dialed is in use, blocking is an indication that all of the lines are in use. In general, switching equipment is not designed to accommodate all subscribers communicating simultaneously. Such a structure would represent the ideal system shown in Figure 4.1 [Ref. 35: p. 3].
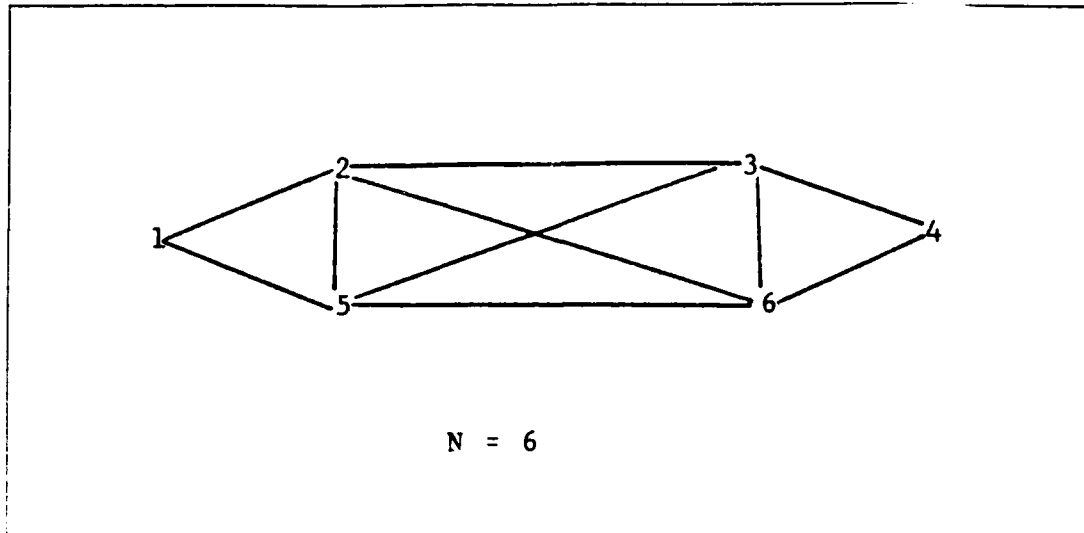
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Figure 4.1   An Ideal Switching System.

In this ideal system, the number of subscribers is repre-
sented by N = 6. The number of possible connections is given
by $N(N-1)$ 2. Such a system is not only impractical, but it
is also grossly inefficient. A more realistic structure
considers the probability that any pair of users would want
to communicate and incorporates that probability into a
capacity maximization function that takes into account,
among other things, budgetary constraints. A more practical
structure is designed to accommodate a certain percentage of
calls made during the busy hour. [Ref. 36: p. 18]. For a
company in the communications business for a profit, some
congestion is desirable. Some call attempts will be unsuc-
cessful. The job of the forecaster is to determine the
demand during the busy hour so that the economists can
formulate an equation to maximize profits. Through sensi-
tivity analysis, it is now possible to determine an accep-
table level of congestion that will generate an acceptable
percentage of subscriber complaints per total number of
blocked calls. Put another way, the congestion problem is
really a problem of determining optimal capacity in terms of
the number of trunk lines.

In 1923, K.O. Moe determined what was considered to be a rational approach to assessing optimal grade-of-service. Moe's principle, as it is called, says that the optimal number of trunks can be reached when the marginal cost of adding a trunk is equal to the amount of revenue directly attributable to it. [Ref. 36: p. 152]

1. Congestion and Message Switching

Congestion in a message switching system is not quite as apparent to the user as with the telephone example. In a store-and-forward system, congestion manifests itself in the form of a delayed, or in rare instances, a lost message. Delays are often the results of too many messages in the system or pre-empting in the queue by a higher precedence message. Messages are sent in sections and reassembled at each node before forwarding to the next node and if a higher priority message is received before the entire lower priority message, the lower message is temporarily stored in a buffer until the higher precedence message has been received completely and subsequently forwarded. [Ref. 37: p. 195].

2. Congestion and Navy Messages

The previous section points out that the problem with congestion in message switching systems is one of delay. In the military, in general, and in the Navy, in particular, such delays are acceptable for routine message traffic. However, during a crisis situation, such delays can be costly, possibly resulting in mission failure or even loss of life. The Pueblo Incident is one such example. One way of reducing the delay for some messages is to assign precedence. Another way that the Navy attempts to alleviate the system-wide problem is through such administrative measures such as impossing MINIMIZE and having the individual responsible for releasing messages during that time period indicate on the message that MINIMIZE was considered. In

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addition, the individual must put his or her signature on the message itself.

The Navy is not considering determining demand for the purpose of accommodating more message communications. The primary interest the Navy has in the amount of traffic that passes through its links is in reducing the demand for message service by educating individual users and by getting them to use self-impose restrictions for the benefit of all. A measure that is under consideration is examining message content to determine whether the message is administratively or operationally oriented.

3. Controlling Congestion--Containing Demand

One of the major problems that government agencies and probably many large private firms have with controlling the demand for telecommunications service is, more than likely, a problem with assessing individual demand within an organization versus assessing the demand of the aggregate. Many studies assume for convenience that the sum of the individuals will be the aggregate. That may be true. But, it is difficult to use the same determinants because many individuals in an organization do not view the problem of congestion from a system-wide perspective. They look at it only from the way that they are personally affected. The author believes that this is a significant issue that warrants further study beyond the mere mention that it receives here. Whether or not the similarity between private organizations and government agencies ends here is open for debate. However, there are a number of differenced that the author believes complicates demand assessment for the Navy above and beyond those complications that government organizations have. That is the topic of the following section.

E. NAVY'S DETERMINANTS OF DEMAND

On initial survey, one may be tempted to presume that the demand for Navy telecommunications service can be expected to be very closely correlated to the demand for similar services for an organization of comparable size. While demand may in fact, be the same or nearly the same, the approach would be too simplistic. The author does not propose that the idea be summarily dismissed because, it would certainly be a relatively inexpensive techniques. However, while the approach may be an acceptable one as a starting point for assessing demand for services for an organization with the same or similar functions, it is the contention of the author that the goals and objectives of private industry and government organizations are too dissimilar to be assured of all but a small degree of correlation, especially without a very detailed study. Furthermore, the author contends that the determinants of demand for telecommunications services by military organizations are very dissimilar to the determinants for other government organizations. First of all, government agencies' goals are ideally set by the citizens who are being governed, while the goals of private organizations are primarily established by its owners, shareholders or a governing board of directors. Second, most private industry organizations would like to ultimately realize a profit, while government organizations are geared toward the accomplishment of a series of goals or a mission. And finally, military organizations have special requirements levied upon its telecommunications equipment that strongly impact upon the demand for some kinds of telecommunications services that have no civilian applications.

1. Mission Versus Profit

Determinant of demand amount to the underlying causes for consumers preferring one good or service as

opposed to another. Determinants consists of a group of independent variables (such as price) and dependent variables (such as quantity) that may be correlated in some way. Without the benefit of supporting data and documentation, the author can only hypothesize the determinants for the demand for Naval telecommunications services. Table VI is presented for consideration as a place to begin.

TABLE VI

PROPOSED DETERMINANTS OF NAVY DEMAND FOR
COMMUNICATIONS

Dependent Variables

.The number of messages originating from a Navy
 unit and terminating in another Navy unit

.The number of messages originating from a Navy
 unit and terminating in another non-Navy military
 unit

.The number of messages originating from a Navy
 unit and terminating in another non-military
 government agency

.The number of messages originating from a Navy
 unit and terminating in a non-government agency

Independent Variables

.average price of a Navy message
.average price of a commercial telegram
.average price of a commercial phone call
.average price of an AUTODIN hook-up
.average price of a round-trip military flight
.average price of a round-trip ship deployment
.average transmission time for a Navy message
.average time to connect for an AUTOVON call
.average time to connect for a commercial call
.defense condition (posture)
.quality of service
.speed of service
.security
.reliability
.mission requirements
.business connection with organization called
.accessibility of system
.familiarity of system
.relative echelon/chain-of-command

2. Selecting an Appropriate Model

Table VI represents a modified version of Table I, the general determinants of demand for a telecommunications service, presented in Chapter III. The determinants have been tailored to accommodate the some of the unique requirements of Navy communications. This section will evaluate the models presented in Chapter III for their applicability for use by the Navy.

a. Access Models

In reviewing the assumptions that are made in structuring the access models, Rohlfs Theory of Interdependent Demand and the Uniform Calling Pattern Model, it is immediately apparent that the use of binary variables used to indicate whether or not a user is a subscriber to the network or not is not an applicable assumption for a military model. Virtually all Navy commands are subscribers to the Navy's message switching system. Therefore, the resulting utility functions have no use in a Navy model.

On the positive side, the Uniform Calling Pattern Model does provide a possible explanation for the growth in demand for telecommunications service even though there is no growth in the population. From the Navy's perspective, this phenomena represents a real and observable behavior in that there appears to be an increasing demand for message communications despite the fact that there has been no real growth in the number on commands being serviced by the message system. Another useful aspect involves its capability for defining user sets based on utility and numbers of members in the set. With modifications, the Uniform Calling Pattern demand curve may allow a graphical representation of the relationships between different communities within the Navy. This may be beneficial in assessing demand as a function of specific mission requirements.

b.   Model for International Demand

Rea and Lages' models for assessing the demand for intenational telecommunications service may have some applicability, at least up to and including the point where they propose a functional form for direct estimation of elasticities.   Elasticity represents a measure of the responsiveness of demand to changes in the quantity of a good consumed to changes in the price of the good.   While the model may be valuable from a private industry perspective, it will require some modifications for Navy use.   For example, there are other considerations such as security, reliability, speed of service and survivability that may override any concerns over the price.   It would be a simple matter to rename the variables and to attempt to estimate the responsiveness of demand to changes in the number of messages sent/received as a result of changes in the level of security or current defense posture.   The big problem would be determining the significance of the information.

c.   Usage Models

The models for usage would be relatively easy to implement since both NAVCOMPARS and LDMX systems are designed to maintain accurate records regarding the transmission of data and information for both source and destination addresses.   Any of the econometric models may be employed to determine use and forecast future demand for Navy message services.   The difficulty in selecting an appropriate model in this particular case is no different from selecting a model for private sector use.

d.   Box-Jenkins Models

This group of models are among the accurate for forecasting short- and medium-ranged data.   However, the Box-Jenkins models are also among the most difficult to interpret and among the most expensive.   This group of models is quite useful for forecasting seasonality.

Unfortunately, neither this model nor any other is very useful when there are unprecedented events or occurrences that may appear in a time series analysis to be spurious data points. In a military crisis, the spurious data may represent a period of time where supply can not be adjusted to meet the demand. The smoothing that will be used will eliminate those data points.

     e. Holt-Winters Model

Like the Box-Jenkins, the Holt-Winters model is particularly strong for predicting seasonality. While for civilian organizations seasonality may coincide with holiday period communications, the seasonality in Navy messages may easily be attributable to exercise activity or heightened politico-military tension somewhere in the world. The need for using the technique may be difficult to justify since for exercise activity, managerial intervention may call for emission control (EMCON) or MINIMIZE in order to reduce communications use. The one primary concern of any military organization is that major events can not be predicted since they are not cyclical. A causal model, perhaps one that focuses on the interdependent relationships among such variables as economic conditions, politico-military environment, and historical analysis may prove more beneficial for forecasting demand in much the same manner that such variables are used by the Intelligence Community.

V. CONCLUSIONS AND RECOMMENDATIONS

A. SUMMARY

This thesis began with an overview of the problem of assessing the demand for goods and services by introducing a number of types of models that are being used by economists. That segment was followed up by a presentation of several models that have been specifically designed to aid in the predicting of demand for telecommunications services, especially by the private industry. Those models were evaluated by the author in terms of their applications, strengths and weaknesses. Finally, the author discussed the problem of assessing demand for telecommunications services by the United States Navy, evaluating the models presented earlier for their appropriateness for Navy use.

B. CONCLUSIONS

Initially, the author set out to propose a model for assessing demand for telecommunication services by the Navy. In studying several existing models, the author concludes that there may yet be a single model that would be adaptable for Navy use but the possibility hardly seems likely. There are too many idiosyncrasies associated with military communications that are generally not considerations for private firms such as survivability, redundancy, security, and reliability. A model must be designed, perhaps incorporating some aspects of the existing models.

Additionally, there is a problem in designing a model that encompasses the many facets of communicating in the Navy. The original goal was to design a model that would be able to take all of the variables into consideration. Although it might be possible to do that, it would probably be an extremely difficult task. The best way to proceed

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would be to design a series of models that examines the different modes of communicating such as Navy messages, AUTOVON, AUTOSEVOCOM, HF, UHF satellite communications, commercial telephone, and facsimile, to list a few.

C. RECOMMENDATIONS

There are still several models to be evaluated that may prove useful in providing the foundation for designing models for assessing the demand for telecommunications services in the Navy. The author recommends that another study similar to this one be undertaken to critique and evaluate other models for consideration in forecasting Navy demand. For example, a model by R. F. Gellerman links telephone demand to the consumption of electricity. Another similar source worth further investigation are other public utilities such as water and gas companies. Such companies may provide useful models that may be adapted for use by the telecommunications industry.

This thesis merely scratched the surface of the congestion issue as it pertains to the NAVCOMPARS and LDMX systems. This is a major concern for the Navy. Further study would be useful in at least generating ideas for solving the problem. Congestion is more than a concern with message switching systems in the Navy, it also is a problem with telephone circuit switching; in particular, AUTOVON. The way that the telephone companies control congestion is by increasing the cost to the user during the peak demand hours. Users who must pay for the use of a network will be more likely to use the system when the rates are lower if that option is available. Most users in the Navy are personally unaware of the price that the Navy must pay for each message that is transmitted. Therefore, price-elasticity has no valid application for the assessment of demand for Navy message communications. On the other hand, most Navy people are aware of the prices charged for placing

commercial calls and are also aware that they, as individuals, will be accountable for making commercial phone calls unless there is sufficient justification.[6]

And finally, in looking at the demand issue, it became apparent that there needs to be more research done to examine the differences between individual user demand and the aggregate demand. It may be interesting to study behavior of individuals and their perspective of the problem of congestion and compare that to the view from the management side of the issue. A more realistic look at system-wide congestion may be presented in an instructional or informative manner directed toward the user. A better understanding of congestion and the impact that an individual user has on the system may benefit all users.

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[6]Usually, if there is no less expensive alternative such as AUTOVON, FTS or WATS, commercial phone calls may be made by users with proper authorization.

APPENDIX A
BOX-JENKINS TERMINOLOGY

1. TIME SERIES AND THE WHITE NOISE PROCESS

Taking a random combination of successive observations
will result in a linear combination of variables if the
points are drawn from a time series whose probability
distribution has a mean equal to zero ($\mu = 0$) and a vari-
ance equal to the square of the standard deviation (σ^2).
Also, assuming that the distribution is normal, the sequence
of random observations represents what is called a white
noise process. [Ref. 38: p. 189]. The resulting linear
combination represents a linear filter model. Thus, a time
series model may be defined as a function that transforms a
white noise process into a time series. [Ref. 38: p.
189-190]. An equation that summarizes the above is

$$x_t = \mu + \psi_0 \varepsilon_t \qquad \text{(eqn A.1)}$$

$$+ \psi_1 \varepsilon_{t-1} + \psi_2 \varepsilon_{t-2},..''$$

or

$$x_t = \mu + \Sigma \psi_j \varepsilon_{t-j} \qquad \text{(eqn A.2)}$$

Where ψ_j ($j = 0,1,...$) are generally referred to as weights
and μ is a constant that determines the level of the
process. Generally, $\psi_0 = 1$. Equation A.1 may also be
expressed in terms of a backward shift operator, β, written
as

$$\beta \varepsilon_t = \varepsilon_{t-1} \qquad \text{(eqn A.3)}$$

a. Autocorrelation and Autocovariance

Time series models within the Box-Jenkins modelling process are characterized by their autocorrelation functions (acf). Covariance between two observations, x_t and x_{t+k}, is autocovariance at lag k, which is translated to mean that the covariance of the observations in this particular time series are k time periods apart. And similarly, the autocorrelation at lag k is interpreted to be the correlation between two observations that are k periods apart. [Ref. 38: p. 191].

b. Moving Average Process

To gain an understanding of the moving average process, consider again equation A.1 where only the first n weights are nonzero. The moving average process would be defined as

$$x_t = \mu + \varepsilon_t - \theta_1 \varepsilon_{t-1} \qquad \text{(eqn A.4)}$$

$$- \theta_2 \varepsilon_{t-2}, \cdots \theta_n \varepsilon_{1-n}$$

Where $-\theta_1$, $-\theta_2$,... $-\theta_n$ are a set of finite weights from equation A.1[7] Equation &mavg1 would be called a moving average process of order n, or simply MA(n). And since there are only a finite set of nonzero weights in the MA(n) process, the process will always be stationary regardless of the values assigned to the weights and the mean of the MA(n) process could be simply represented by μ

(1) First Order Moving Average Process.

The first order moving average process, MA(1), is a special case of MA(n). It is represented by equation A.5

$$x_t = \mu + \varepsilon_t \qquad \text{(eqn A.5)}$$

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[7]By convention, minus signs are used on the weights.

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$-\theta_1 \varepsilon_{t-1}$"

The autocorrelation function cuts off at lag 1, which is to say that the correlation between observations in this time series are no more than one period. In essence, the moving average process is stationary for any value θ_1.

(2) Second Order Moving Average Process.

Without going into the mathmatical expression that defines the second order moving average process, MA(2), let it suffice to say that the autocorrelation function cuts off at lag 2 in this case. Thus, the MA(2) process is stationary for all values of θ_1 and θ_2 [Ref. 38: p. 199-200].

c. Stationary and Nonstationary Time Series

Models derived from equation A.1 may be used to represent both stationary and nonstationary time series. To be stationary implies that the time series fluctuates about a constant mean. If a time series has no constant mean, it is said to be nonstationary. To digress momentarily, an explanation of the significance of stationarity may be helpful.

One of the main premises of the Box-Jenkins procedure is that for nonseasonal time series, a series is stationary or can be reduced to stationarity through a process called differencing. As previously stated, a time series is called nonstationary in the mean if it behaves as if it has no constant mean; that is, for any local time period, the observations resembles any other time period except for their averages.

d. Differencing and Stationarity

To observe the effect of differencing on a nonstationary time series, figure A.3 illustrates the iterative process. Figure A.1 and A.2 illustrate the concept. Figure A.3 (a) exhibits nonstationary behavior in both the slope and the mean. The first difference $(x_t - x_{t-1})$ will yield a

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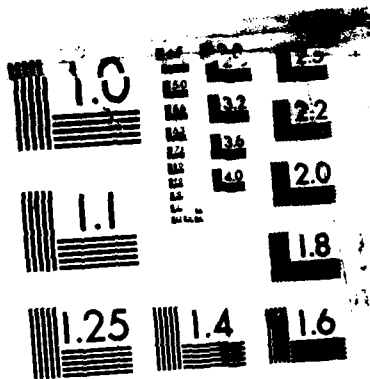MICROCOPY RESOLUTION TEST CHART

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pattern similar to figure A.3 (b). The second difference $\leftarrow(x_t - x_{t-1}) - (x_{t-1} - x_{t-2}) = x_t - 2x_{t-1} + x_1 -2)\rightarrow$, illustrated in figure A.3 (c) represents a stationary time series that can now be manipulated with relative ease. [Ref. 38: p. 204].
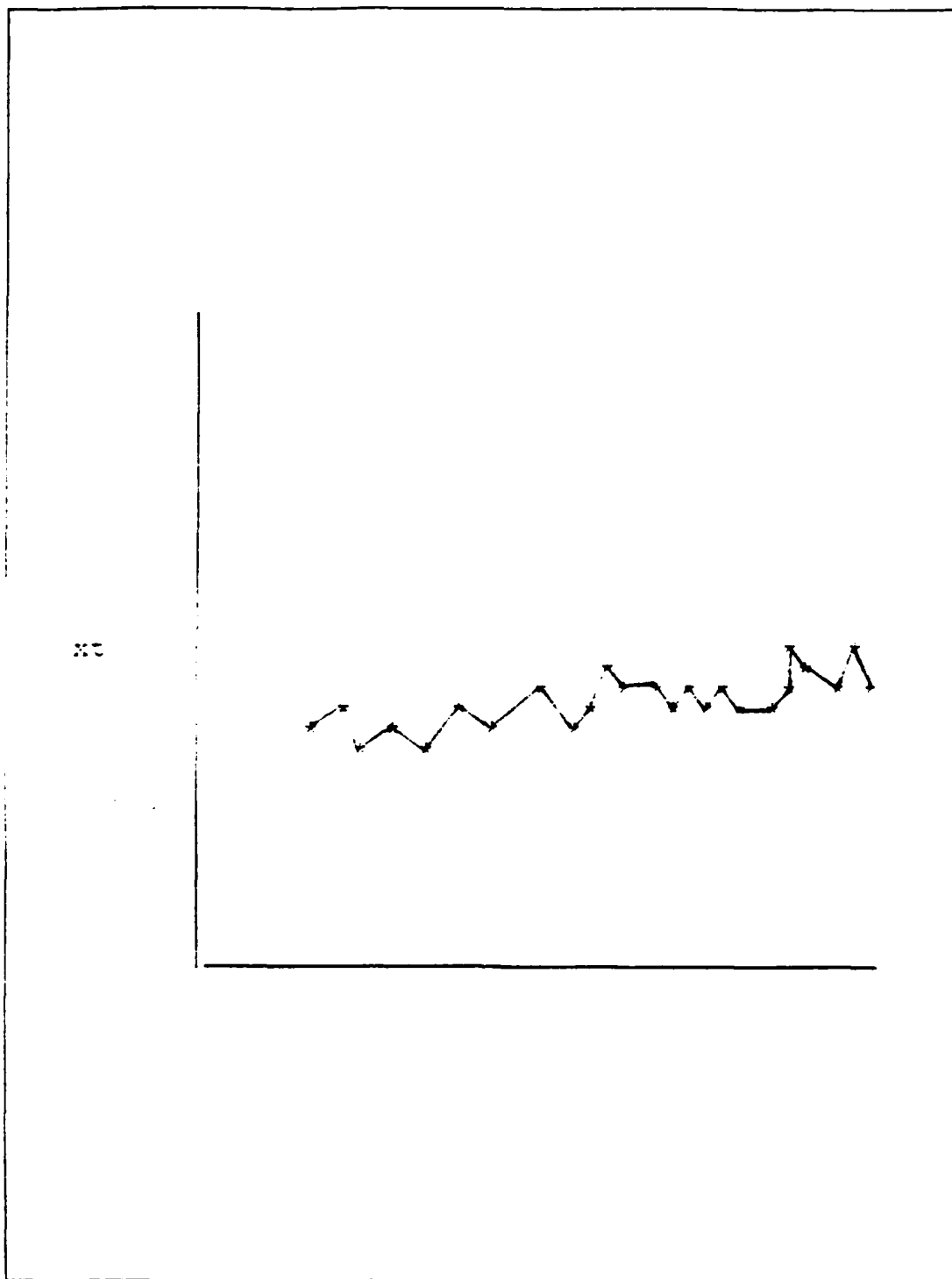
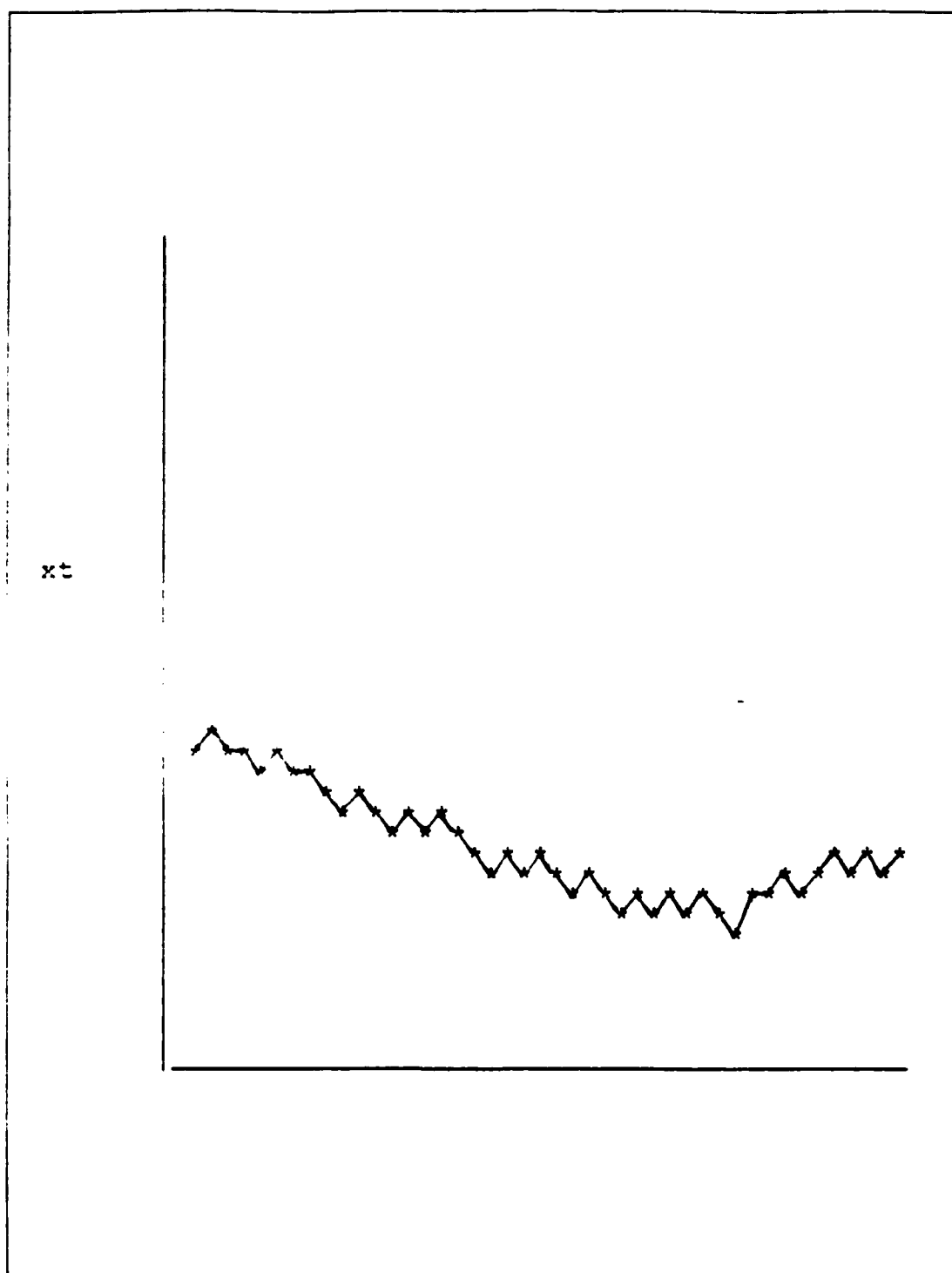Figure A.1   Nonstationary in the Mean.

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Figure A.2   Nonstationary in Mean and Slope.
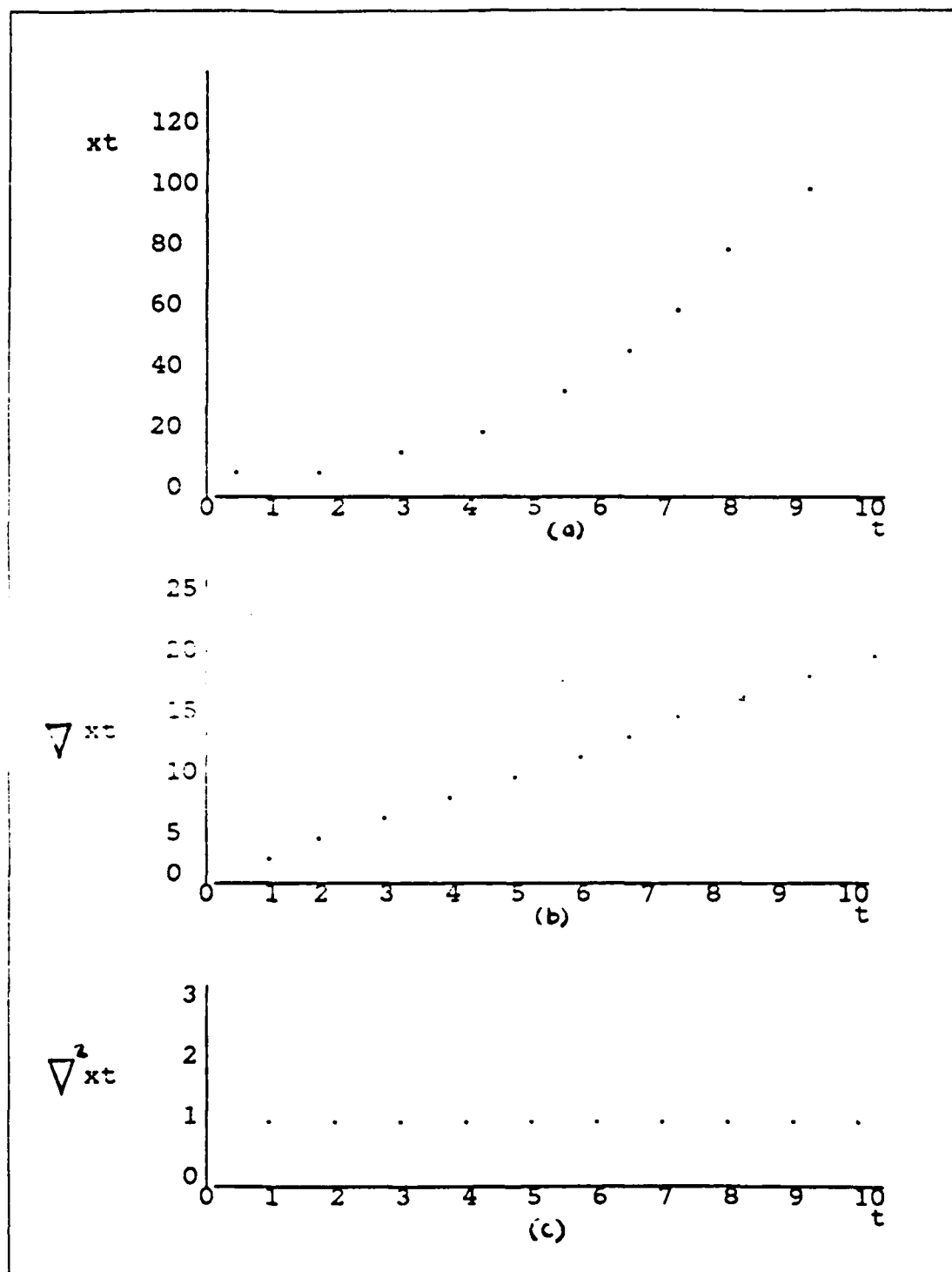
Figure A.3   Successive Differencing of a Nonstationary Series.

APPENDIX B
AUTODIN SWITCHING CENTERS (ASC)

1. ASCS IN CONUS (INCLUDING HAWAII)

    (1) Andrews AFB, MD

    (2) Fort Detrick, MD

    (3) Syracuse, NY

    (4) Albany, GA

    (5) Gentile AFB, OH

    (6) Tinker AFB, OK

    (7) Norton AFB, CA

    (8) McClellan AFB, CA

    (9) Wahiawa, HI

2. ASCS OVERSEAS

    (1) Croughton, England

    (2) Coltano, Italy

    (3) Camp Drake, Japan

    (4) Pirmasen, Germany

    (5) Finegyan, Guam

    (6) Taegu, Korea

APPENDIX C
WORLDWIDE LDMX SITES

1. LDMX (UNIVAX U70/45)

    (1)   NTCC Pearl Harbor, HI

    (2)   NTCC Camp H. M. Smith, HI

    (3)   NTCC Crystal Plaza, Washington, DC

    (4)   NAVCOMMSTA Puget Sound, WA

    (5)   NTCC North Island, CA

    (6)   NTCC Charleston, SC

    (7)   NAVCOMMSTA Roosevelt Roads, PR

    (8)   MTCC Camp LeJeune, NC

2. LDMX (U90/60)

    (1)   NAVCOMMU London, UK

    (2)   NTCC Hampton Roads, VA

APPENDIX <u>D</u>
WORLDWIDE NAVCOMPARS SITES

1. NAVCOMMPARS (UNIVAX U90/60)
   - (1) NAVCAMS LANT Norfolk, VA
   - (2) NAVCAMS MED Naples, IT
   - (3) NAVCAMS EASTPAC Honolulu, HI
   - (4) NAVCAMS WESTPAC Guam, MI
   - (5) NAVCOMMSTA Stockton, CA

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